MAY 13 1935

Engineering News-Record

McGraw-Hill Publishing Company, Inc. May 9, 1935 Twenty-five Cents, Five Dollars per Year

IN THIS ISSUE:

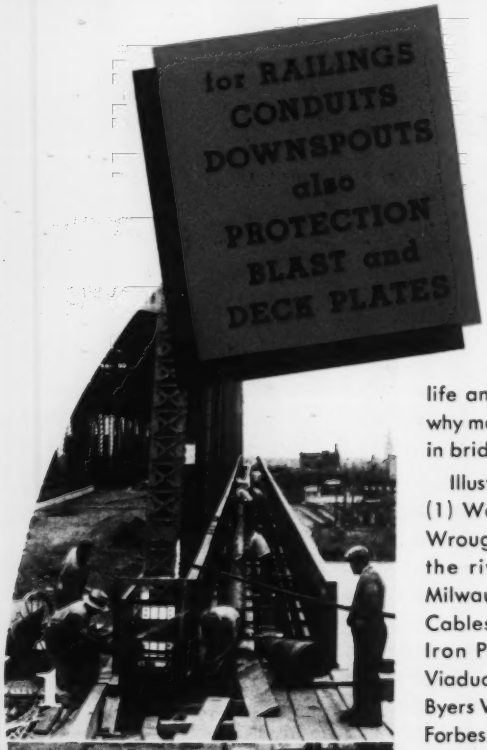
The First Year at Fort Peck

An article reviewing the progress made in constructing the world's largest earth dam on the Missouri River in Montana

Beginning hydraulic fill for Fort Peck Dam inside an embankment of gravel dumped from trains on the trestle

Back on the New Bridges because of long service on Old Bridges . . .

BYERS WROUGHT IRON



BRIDGES, like most other civil engineering projects, are designed to last for generations. Appropriations for maintenance, repairs, and replacements are difficult to secure, and consequently a proper proportion of wrought iron to other materials assures longest life and lowest maintenance. That's why more wrought iron is being used in bridges than ever before.

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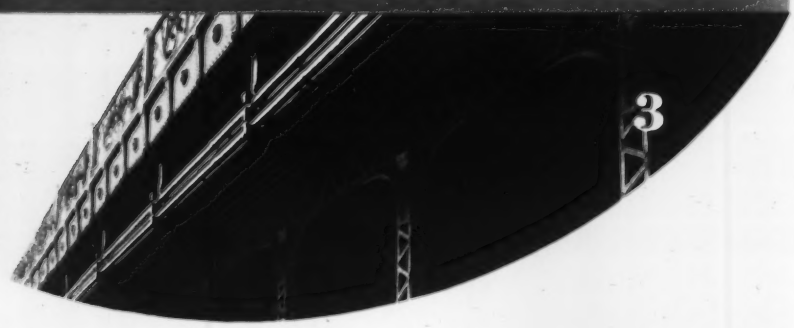

For Construction Unity

IF THE construction industry has learned any one lesson during its five lean years, it is the need for better coordination between its constituent groups. From its nature a subdivided and dispersed industry, construction, in a crisis, must either risk piecemeal discomfiture or improvise for the occasion some more or less effective joint action. Neither of these solutions is satisfactory or a credit to the statesmanship of the industry.

What can be achieved through unified effort, even when inadequately financed and implemented, is indicated by the record of the Construction League. In 1931 the League was scarcely more than a conference group with slender resources. Yet, through its Committee on Trade Recovery, it financed and directed a nationwide effort in behalf of a public works policy that has meant much to the industry. Later, when the National Recovery Act required the codification of industry, it was the Construction League which, through its Code Committee, made it possible to coordinate the various divisions and subdivisions of the industry. These are but two instances of valuable service, more conspicuous but scarcely more useful than a number of other achievements.

WHAT though none of these efforts may have achieved 100 per cent? What though every individual of each group may not be wholly satisfied with all that has been accomplished? What though all of the groups may not have come through unreservedly with full cooperation or support? Such shortcomings do not signify failure; rather do they emphasize the magnitude of the accomplishment. For it is no mean success to have inspired in an industry, so long unintegrated, the joint action that has made possible the progress already achieved.

Moreover, the fact remains that for the first time in its history the construction industry has set up a standard to which every last subgroup may rally and has offered a leadership that has won a respectful hearing in behalf of the vast interests involved in the second largest of all our industries. Whether or not the Construction League as set up has been the ideal spokesman for the industry, it was the only agency available. And, as a matter of fact, it has done its job well. At all events, it has served to demonstrate that in a pinch the industry must turn to more effective integration; and that in order to realize this, it will promptly avail itself of the most available agency.

All of which should encourage those who now are working to establish the League on a sounder basis. The lessons of adversity should teach us the value of a truly representative and stable body to perform in behalf of the industry and its constituent groups those functions that should involve joint counsel and effort. Engineers, architects, contractors, subcontractors, producers and distributors of materials and equipment—all these have a heavy stake in a well-considered, representative and energetic handling of those industrial and public matters which touch the welfare of the industry.

THIS is no time to defer to the misgivings that often are invoked against any proposal to effect the coordination of existing organizations. Here there can be no rational fear of usurpation or disproportionate influence. Existing organizations, by their very survival through these troublous times, have demonstrated their value to their respective groups. None need surrender one ounce of its authority within its field; within the League each can carry on for its own group just as effectively as ever. Coordination, in fact, adds to its capacity for accomplishment by providing an opportunity for it to participate in the counsels and the influence of a joint effort. Each can deal more constructively with its external affairs if it can enjoy the cooperation of other groups. Conflicts between groups can be composed rationally within the industry and policies for the industry as a whole can be formulated and advanced with a united front. In union surely will be found external strength with no conceivable sacrifice of group autonomy.

No one of the groups cited in the foregoing is outside the pale of the benefits that can accrue to the construction industry through the establishment of an effective coordinating agency and a worthy joint spokesman. No one of them can afford to pass up the present opportunity to realize that objective. The partial unity achieved under the stress of emergency is an object lesson of what can be done with meager resources; it is an earnest of the greater accomplishment that will be made possible through a truly representative Construction League, wisely led, adequately staffed and soundly financed.

Willard Chevalier

ENGINEERING NEWS-RECORD

Published every Thursday. Vol. 114, No. 19. Price 25c. per copy. Subscription, domestic, Mexico, Central and South American countries, $5 per year. Canada, including duty, $7.50. All other countries, $9 a year or 36 shillings. Entered as second-class matter April 11, 1917, at the Post Office at New York, N. Y., under the Act of March 3, 1879. Printed in U.S.A. Cable Address "McGrawhill, New York." Member A.B.P. Member A.B.C. Copyright 1935 by

McGRAW-HILL PUBLISHING COMPANY, INC., 330 WEST 42d STREET, NEW YORK, N. Y.

Editorial and Publishing Offices: 330 West 42d Street, New York; 520 North Michigan Avenue, Chicago; 883 Mission Street, San Francisco; Aldwych House, London, W. C. 2, England. Branch Offices: Washington; Philadelphia; Cleveland; Detroit; St. Louis; Boston; Greenville, S. C.

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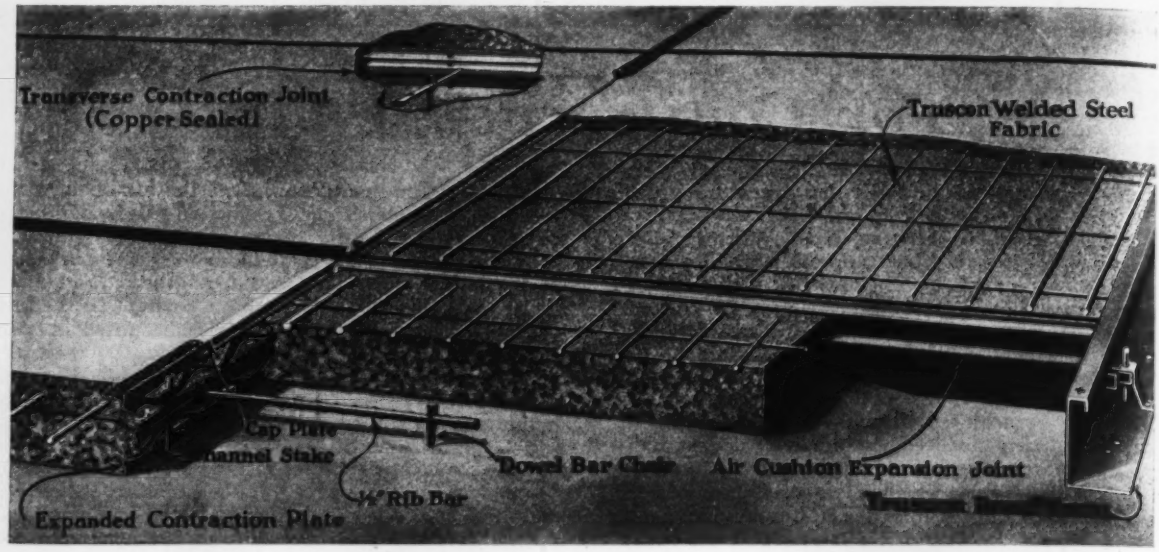

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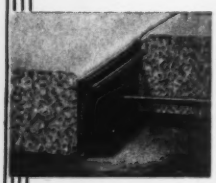
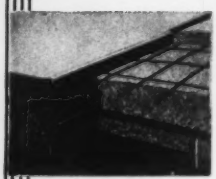
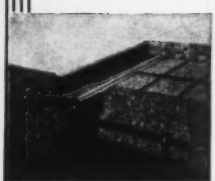


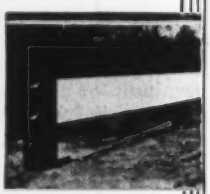
Air Cushion Expansion Joints



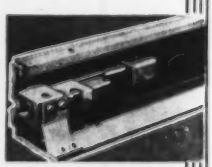
Expanded Contraction Plates



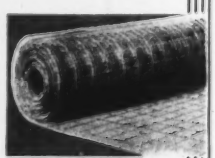
Transverse Contraction Plates



Guard Rail



Steel Road Forms



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In the News:

Inclusion of seacoast erosion work and flood control in the matters assigned to the new Resettlement Division of the relief-works activities is the first federal recognition of these types of improvement works.

General Belief in the futility of the Presidential order of last summer, authorizing as much as 15 per cent discount from code price limits in bidding to governmental agencies is confirmed by an official report on the effects of the order.

Approval of Chapter II-B, for heavy and railroad construction, brings the construction code nearer completion, but there is still no action on the architects' and engineers' chapters.

A South Dakota Surveying Student enriches the lexicon of engineering by a new definition: "A datum plane is a plane on which the level is set to distinguish the elevation and location of points on that plane. Notes taken on that plane may be called *data*."

Western Dispatches took on a different tone last week. Instead of dust storms the Great Plains drought area reported rain and snowstorms, with floods heavy enough to wash out small bridges. But much heavier precipitation is reported from Bahia, Brazil, where the total fall in five days last week is estimated at 60 in.

Though the working season is advancing, Washington has taken no action to release road money from the relief-works appropriation. One of the perplexing points is how to apportion the money according to the formula prescribed in the act between the states, and at the same time fit their respective volumes of unemployment. As to city projects, no ruling on use of loans only or loans and grants has yet been announced. The amount of "security wage" to be paid is under discussion at present.

The Grandiose Plans of New York City for $150,000,000 worth of federal aid slum-clearance housing were put in the form of an application to the WAD of the new relief-works organization May 4. Four huge projects are said to be contemplated by the Municipal Housing Authority, which proposes to sell its bonds to the federal government for the necessary cash.

House and Apartment Building for the first four months of 1935 is far ahead of the same period last year, according to a survey made by the National Association of Building Trades Employers. In some cities the increase is more than 100 per cent.

In This Issue:

Fort Peck Dam is to be so large that the preliminary operations themselves would be considered notable undertakings on any lesser undertaking; for example, 4,100,000 cu. yd. of stripping. These preliminary operations are reviewed in this issue in the first of two articles on the great dam. The second article will describe tunnel operations.

Air Movements, Storms and other meteorological happenings of significance to works built by engineers are discussed in the sixth article on the relation of aerodynamics to the civil engineer.

John F. Stevens, in the fifth article of a series of recollections, tells how he discovered Marias Pass, the route by which the Great Northern Railway gets through the Rocky Mountains without a tunnel; this is probably the most dramatic incident to Mr. Stevens' long career.

The Advantages of welded connections to meet special conditions are exemplified in the new Palmer C. Ricketts Laboratory at R.P.I.

Four Steel-ribbed Domes, the largest 85 ft. in diameter, built for the Griffith Observatory at Los Angeles, were designed by the use of a new method of analysis that simplified a complex problem and resulted in an economical design. Welding also was used extensively on this job.

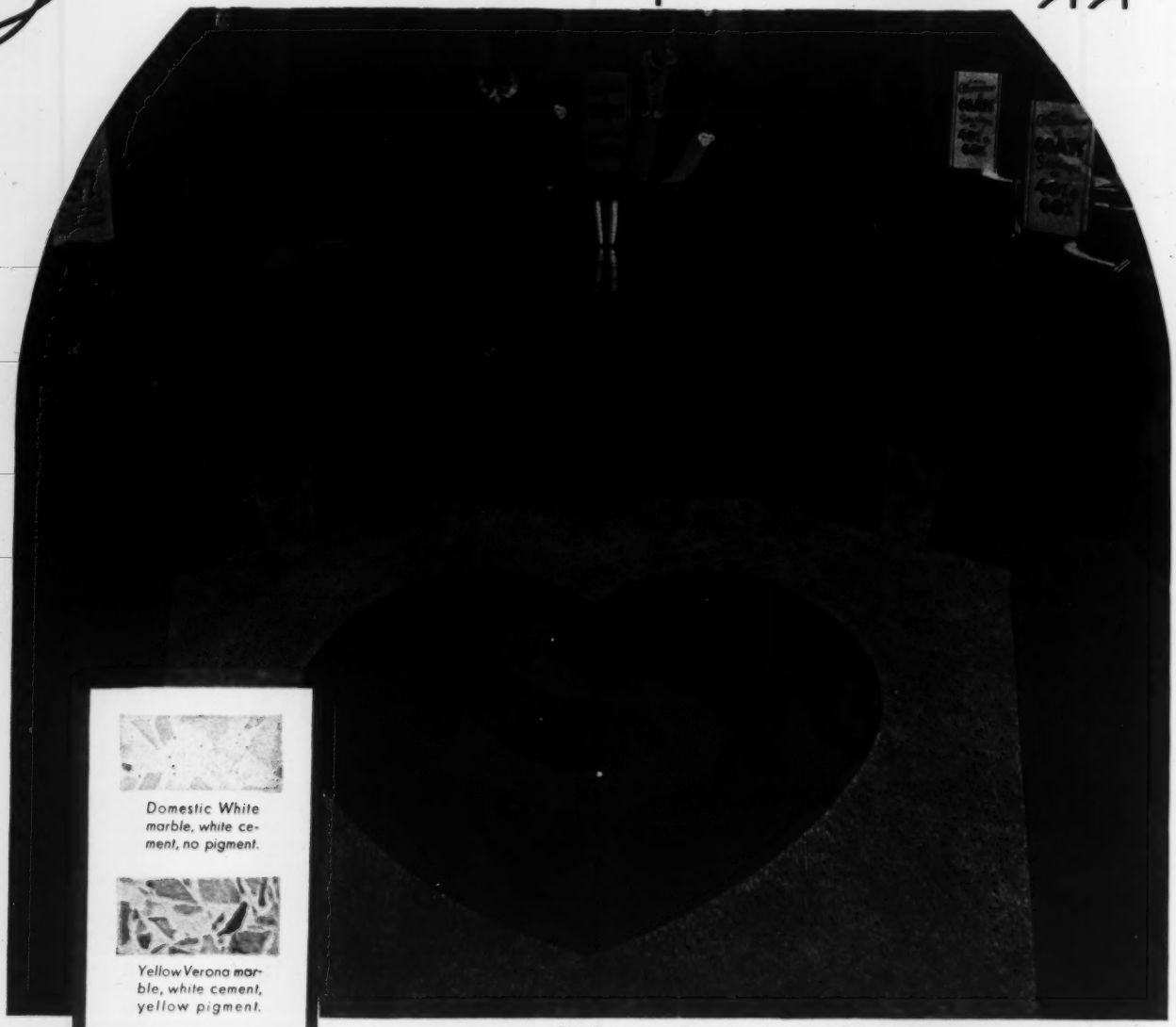
A Highway Bridge of interesting design has been built at Norfolk, Va., to replace an old and narrow timber trestle. The new structure combines steel and reinforced concrete in a manner calculated to give a simple and easily maintained structure.

The Fuel Value of Sewage Sludge is an important element in any plan for the disposal of sludge by incineration. A formula for its determination in terms of volatile-matter content is presented in this issue.

Waterworks Report

Papers, discussions, exhibits and other happenings at the Cincinnati convention of the American Water Works Association will be reported in the May 16 issue.

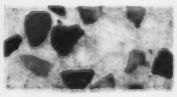
Durable Beautiful Terrazzo



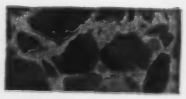
This fine terrazzo floor, photographed in full natural color, is in the entrance to Sallinger's Department Store, Boston. Made with Atlas White portland cement. Freeport Marble & Tile Company was the terrazzo contractor. Sumner Schein was the architect. Both of Boston.

Domestic White marble, white cement, no pigment.

Yellow Verona marble, white cement, yellow pigment.



Blue Turquin marble, white cement, blue pigment.



Red Verona marble, white cement, red pigment.

Belgian Black marble, white cement, black pigment.

These actual-size, true-color samples of fine terrazzo illustrate marble and pigment combinations similar to those used for the floor shown above.

With marble chips, white portland cement, color pigment and metal strips the terrazzo contractor builds you a floor of fine terrazzo. It may be bright with vivid color, or soft in pastel shades; it may be bold and striking in pattern, or subdued and unobtrusive—exactly according to *your* requirements. Because each fine terrazzo floor is designed to order, custom-made to fit *your* needs. Once installed this floor will wear like concrete (it is a form of concrete). It will be easy to clean, inexpensive to maintain. And its colorful, cheerful surface will *stay* that way. Ask your architect or terrazzo contractor. Or write Universal Atlas Cement Co. (*United States Steel Corporation Subsidiary*), 208 South La Salle Street, Chicago.

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ENGINEERING NEWS-RECORD

May 9, 1935

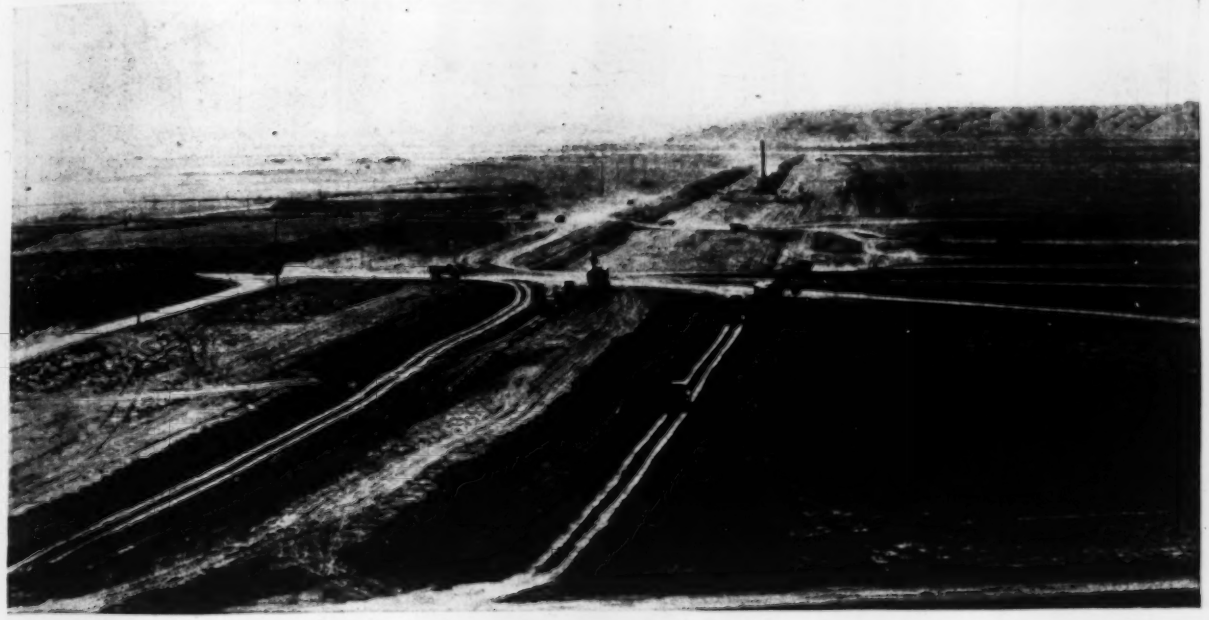


FIG. 1—THE BASE OF FORT PECK DAM being stripped of 4,100,000 cu.yd. of earth as a preliminary operation to constructing the main dam of over a 100,000,000 cu.yd. of hydraulic fill. The base area shown is about 9,000 ft. long and 4,000 ft. wide.

A Year's Progress at Fort Peck

Constructing the Servicing Adjuncts

Building railways, roads, power lines, a city for 8,000 people, four hydraulic dredges and hundreds of boats, barges and pontoons taken in the stride of starting dam, diversion tunnel and spillway structures

VARIETY and stupendous volumes of construction are the first impression of the engineer upon viewing the operations at Fort Peck a year after the beginning of construction. As the actual quantities and dimensions are visualized, the marvel of magnitude is emphasized. Only a Boulder Dam or the Mississippi flood-control operations occur to one as justifying inclusion in the same category as the movement of earth and concrete at Fort Peck. Comparisons, however, convey only a vague picture; the actual quantities are needed to make outline and perspective clear. A review of the year's work, therefore, begins with a recital of volumes and dimensions.

IN ALL THE GENEROUS NUMBER of great engineering construction works of the last ten years few present elements of greater interest than the hydraulic-fill dam and its collateral spillway and diversion tunnels now being constructed on the Missouri River at Fort Peck in northern Montana. Estimated to cost $86,000,000, the dam is the largest earth dam in the world. The general engineering features and the economic purposes of this work have already been discussed (*E.N.-R.*, Nov. 29, 1934). Work had then been in progress about twelve months. What had been done in this time? To put this construction story before the readers of *Engineering News-Record*, a visit to the operations was made by the editor and, based on his observations, this and a following article have been prepared. These articles present a record of ordered activity that commands attention for its speed and definite purpose.

—EDITOR.

At present, most figures must be the round numbers of advance estimates. To begin, Fort Peck Dam and its collateral works indicated by the works map (Fig. 2), are estimated to cost $86,000,000, and of this sum $50,000,000 has already been allotted by the Public Works Administration. The three main structures are the dam, the diversion tunnels and the spillway. The dam calls for 100,000,000 cu.yd. of earth-fill (mostly hydraulic fill), 4,000,000 cu.yd. of gravel in upstream and downstream toe fills, 1,600,000 cu.yd. of rock riprap facing and 4,100,000 cu.yd. of stripping excavation for the base. The four diversion tunnels, of 6,317-ft. average length, are 32 ft. in unlined diameter

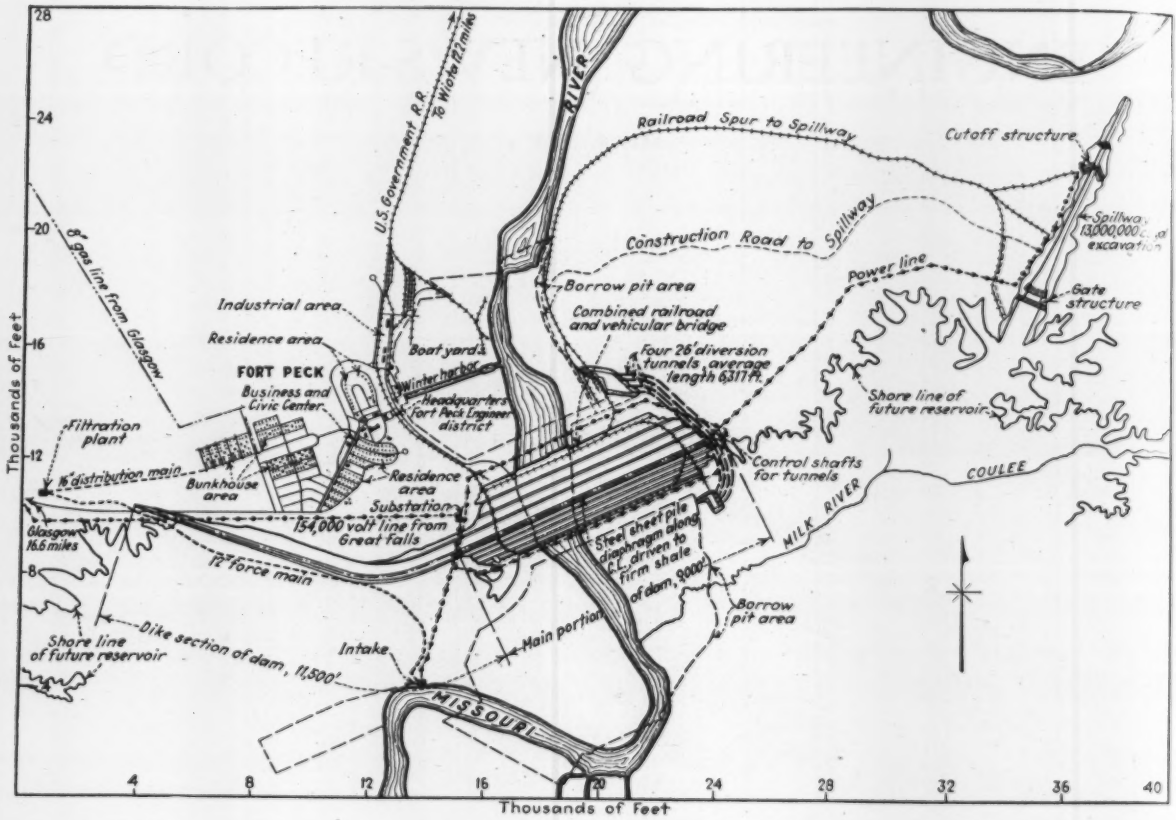


FIG. 2—LOCATION MAP of work services and structures for the 20,000,000-acre-ft. storage reservoir at Fort Peck in Northern Montana.

through faulted shale, which disintegrates rapidly upon exposure to the air. About 500,000 cu.yd. of concrete will go into the lining of the tunnels and their gate and outlet structures. The spillway calls for 13,000,000 cu.yd. of excavation and 540,000 cu.yd. of concrete. This work, with its servicing adjuncts of railway, roads, power lines and residential quarters and workshops, is scattered over an area of roughly 5x9 miles; the true locations and distances are shown by Fig. 2.

Such volumes and spread of construction called for servicing adjuncts that were themselves construction operations of considerable size. The main items are a 13-mile railroad to the dam, a town for housing 8,000 people, a bridge and trestles 6 miles long over the river and along the toes of the dam, spur tracks to the tunnel and spillway operations, a boat yard for constructing the four hydraulic dredges, barges and other floating equipment, and a 288-mile power-transmission line and substation. All of these main service structures had their necessary adjuncts, and there were of course numerous units of construction equipment, some of which will be referred to in more detail later on.

In point of time, the construction of the servicing facilities naturally had precedence, although in a very short time operations on the project structures were proceeding simultaneously. A quick look at the order of work is helpful in understanding the accounts of separate operations. At the beginning it is important to recall that Fort Peck was a work-relief operation, and the schedule was purposely crowded to give employment as rapidly as possible.

A speedy progress schedule

Actual construction was begun Oct. 23, 1933, although engineering studies had been in progress from a much earlier date. On the date named 70 men began clearing up the site for the boat yard, so that an early start could be made with the heavy task of dredge construction. By the end of the week 250 men had been employed, but before employment could be greatly multiplied access to the work by railway and road was essential. So, besides the 250 men on the site, the end of the first week saw three locating parties busy staking out the branch railway to the dam from Wiota on the Great Northern Railway. By Nov. 3 there were 470 men at work clearing the boat-yard site, on the site of the dam and on the 13-mile railway branch.

But earlier access was wanted than possible completion of the railway would provide, so about Nov. 10 road graders started to improve the country roads leading to the dam; then maintenance under the heavy hauling kept them busy all the winter. By the time road-grading was started about 600 men were at work, a portable sawmill was in operation, and barracks and mess-hall construction was started. On Nov. 15, to relieve local unemployment, a contract was let to gather and stockpile 300,000 cu. yd. of riprap boulders for future use on the slope of the dam (Fig. 3). This work was located at Saco and Malta, about 90 miles away on the Great Northern Railway, with which, as just stated, the branch railroad to the dam was planned to connect. Two days later, Nov. 17, six parties of surveyors started the location of the 288-mile government power line from Great Falls, Mont., and the Montana Power Co. began constructing the temporary 50,000-volt power line from Whately, Mont.

Operations now turned more to direct construction. On Dec. 11 work was started on an experimental tunnel, to determine how best to handle the shale rock through which the great diversion tunnels were to be built. On Dec. 15 government barracks were started, and the day before the truck-hauling of 2,500 tons of material with which to start the dredges was contracted for on Jan. 3, 1934, a telephone line from Glasgow to Fort Peck, the newly named town at the dam site, was started. A week later boat-yard workers moved into newly completed barracks, and on Jan. 15 work started on the first dredge hull; power was turned in over the temporary line.

FIG. 3—STOCKPILING FIELD BOULDERS for the 1,600,000 cu.yd. of riprap that will be placed on the reservoir slope of 100,000,000-yd. hydraulic fill at Fort Peck Dam.

Mention of these early operations has been made in some detail, to indicate the purpose of the engineers to give quick employment and not depart from orderly procedure. Naturally a northern Montana winter did not make the task easier. While the winter was considered mild by the natives, on several occasions the thermometers registered 30 deg. below zero. Roads to Glasgow, of dirt only, were difficult to negotiate, and hand shovels were always carried for digging the cars out of snow or mud. Core-drilling started in the early spring during freezing weather and was carried on within sheds; stiff frozen clothing was the price of getting wet. When the snow melted in February, a sea of mud resulted and workmen sought lodgings in farmhouses, barns and sheds to avoid the trip to Glasgow, which was the nearest town and the original headquarters of the engineering forces.

Service railway and trestles

With some of the works-cataloging out of the way, attention to individual operations is possible. The first of these was railway service. Railway construction may be considered as dividing into main-line work, bridge and trestle construction and the building of the spillway spur (Fig. 2).

As stated in *Engineering News-Record*, April 5, 1934, p. 444, the railroad work was pushed 24 hours a day. The principal structure of this 13-mile road was the Milk River Bridge, having three 100-ft. steel through-plate-girder spans. Railway work started Dec. 18 with rented equipment (one power shovel and four dump trucks) and government forces. After a few days, four shovels and eleven trucks (8-yd.) were in operation, and later nineteen large trucks were in use. By March 22 rails were being laid at the rate of 1 mile a day and ballasting had started; on April 16 the railroad was formally opened. The rolling stock had crossed the Milk River Bridge a month previous, since the falsework had been built strong enough to support trains. A 6-mile extension to the site of the spillway was not completed until November, 1934, since its construction could be greatly simplified by the prior construction of the bridge over the Missouri River.

At the dam site the railway develops into an elevated loop encircling the main dam, as shown by Fig. 2 and to larger scale by Fig. 4. Including the trestle ramps to the spurs, lines going to the spillway and to the upstream portals of the diversion tunnels, the bridge and trestles are 31,842 ft. long. The structure is a combination of pile and framed bent timber trestle, steel bent and girder viaduct, a part on concrete piers and a part on pile footings, and a steel truss 200 ft. long over the main channel of the river. The length of steel structure (Fig. 5) is 2,226 ft., or considerably less than half a mile of more than 6 miles of elevated structure. Its location is between the banks of the river in the downstream side of the loop, where ice and flood exposure called for the clearway and resistance provided by steel structure.

The elevated loop is essentially a construction device; its purpose is equally to enable across-stream transportation and to provide an elevated track for making the upstream and downstream

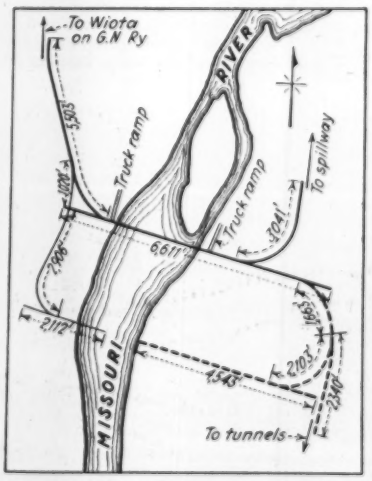
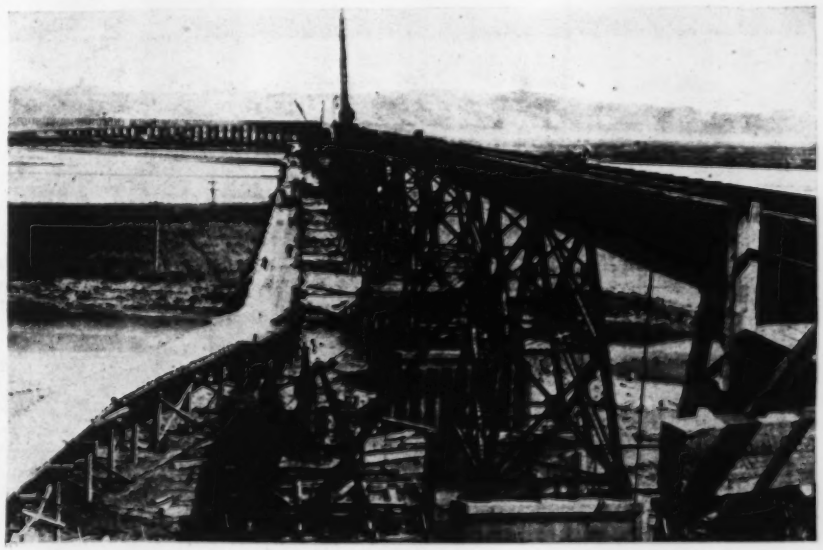


FIG. 4—PLAN of elevated track on timber trestle and steel viaduct that rings the main dam for 6 miles for general railway service and for placing 4,000,000 cu.yd. of the fill by train dumping.

FIG. 5—STEEL VIADUCT of elevated loop railway is located over the river channel; original pile-trestle temporary crossing is shown at the left.



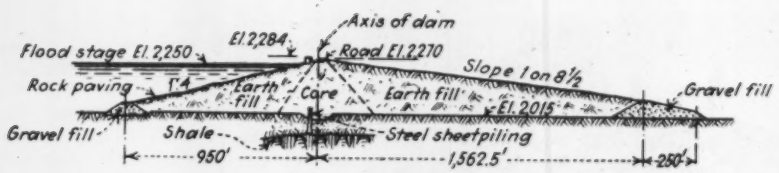


FIG. 6—FORT PECK DAM CROSS-SECTION shows the greatest artificial earth embankment ever built to impound water.

gravel toe fills (Fig. 6) by train dumping (Fig. 7). For its purpose the top of rail is 60 ft. above water surface, or 2 ft. above the top of the gravel fill. Design of structure and methods of construction presented no unusual features. The construction was by contract. The Massman Construction Co. had the contract for the Missouri River Bridge; Addison-Miller, Inc., had the upstream tunnel spur and construction trestles on the right bank; and Morrison-Glasscock-Connor had a similar spur and trestle on the left bank. The bridge was begun Feb. 26 and completed Oct. 17, 1934. The construction of bridge and trestles required 2,170 tons of steel, 13,000 piles, 488,000 lin.-ft. of piling, and about 8,750 M. ft. b. m. of timber. These quantities and its length of over 6 miles make the elevated loop an impressive service adjunct for the construction of a minor part of the earthfill even after discounting its general transportation purpose, but the amount of fill it will place is 4,000,000 cu. yd. which is a sizeable earth-moving operation.

Electric-power services

The need of railway transportation at Fort Peck was no more immediate than was the need of power. Temporarily the 50,000-volt line from Whately would serve, but much greater amounts of energy were required when the construction activity that was contemplated was in full progress. As stated, the engineers decided to go 288 miles to Great Falls, Mont., for the power they wanted. This called for rapid transmission-line construction. The 288-mile line was completed in 120 days, which is something of a record even for a process with the reputation of power-line construction for fast going. The structure was simple: two-pole supports with a 29-ft. cross-arm carried the cables 14 ft. apart in spans averaging about 600 ft. and running up to twice this length. About half of the line has aluminum cable, and half has copper cable. Conventional line-construction practices were followed; to facilitate construction and maintenance, the line location was kept as close to highways as was practicable.

The cables receive power at 161,000 volts at Great Falls and deliver about 154,000 volts at the Fort Peck substation. At this station the voltage is stepped down to 7,250 for distribution to the hydraulic-dredge feeder-line system. The chief interest to the constructor lies in this feeder system.

The electric distribution system supplying energy to the four electric dredges is laid out to cover the whole area over which the dredges are to operate. At a steel switch structure outside the substation the feeders form four circuits extending north and four extending south from the structure to the downstream and upstream sides of the dam. Three circuits only will cross the river. From the main feeders, lateral feeders are carried into the upstream and downstream borrowpit areas; these laterals are 5,650 and 5,250 ft. long, respectively. At right angles to the lateral feeders, tee-head feeders 600 ft. apart will be installed; as dredging progresses the tee-heads will be removed and rebuilt in new areas. To construct this feeder system, 1,250,000 lb. of copper conductor, 930 poles and eleven steel towers were used.

Dredge cables of three 750,000 circular mil conductors, rubber-insulated and sheathed, about 5 in. in diameter, are used to connect the various sections of

FIG. 7—HYDRAULIC FILL for main dam being started inside the gravel-fill toe being constructed by train dumping from the trestle.

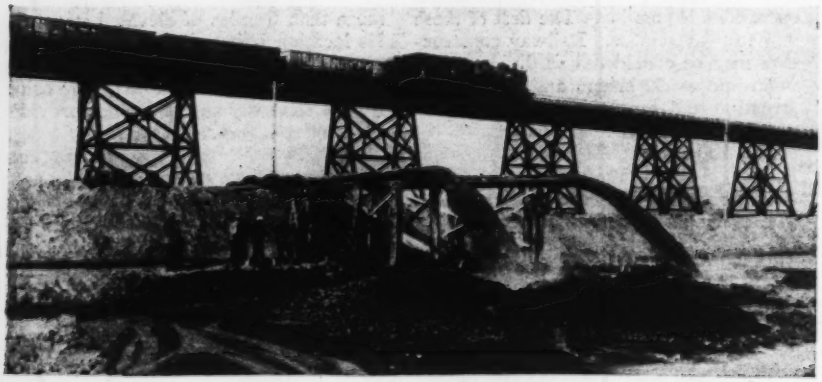
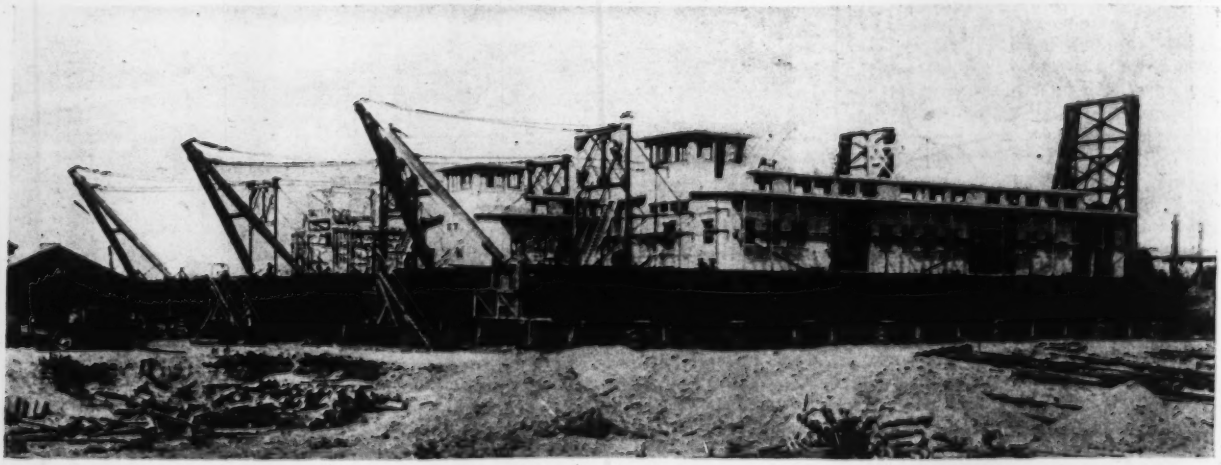


FIG. 8—FLEET of four 28-in. hydraulic dredges on the ways in the shipyard at Fort Peck Dam. Job construction of these dredges was one of the unique features of the preliminary operations.



the dredge unit to the overhead lines of the dredge feeder system. A portable terminal structure, on which are mounted lightning arresters and an air break switch, connects the overhead lines to the dredge cable. The structures are substantial, and factors of safety are large with a view toward minimizing the possibility of failure of electrical supply to the dredges. The dredge-feeder system was installed by the A. S. Schulman Co., Chicago.

Construction town built

With a contemplated four-year construction period, residential facilities were planned to provide convenience and comfort but without elaboration unsuited to a temporary camp.

For housing laborers there are 144 temporary wood-frame bunk houses, eighteen bath houses and nine mess halls. These quarters are divided into nine blocks, so that each block has accommodations for 384 men. In addition, there are three blocks of foremen's dormitories, with eight dormitories and one mess hall to the block. Bathing facilities in these blocks are located in the dormitories. For married employees in executive, administrative and supervisory positions, a group of 264 wood-frame temporary residences has been provided of seven sizes and 36 different types.

A group of public buildings includes a town hall and postoffice, school, employees' hotel, hospital, motion-picture theater, a recreation building and a block of store buildings. There are only thirteen permanent buildings, a two-story administration building and twelve residences for the permanent maintenance staff after the dam is completed. Service buildings include a laboratory, garage and fire station, cold-storage building, commissary warehouse and bakery, laundry, oil-storage tank, gasoline pump house and a foamite engine and house near the oil and gas storage.

Complete water-distribution and sewer systems were installed, the former of 66,300 ft. of cast-iron pipe and the latter 39,000 ft. of vitrified sewer pipe. A 2-m.g.d. purification plant with settling basin, filters, coagulant and sterilization facilities, clear well and pumping station, was built on high ground west of the city. The water intake is above the dam; sewage discharges below the dam. For heating, an 8-in. gas main brings natural gas from Glasgow.

Shipyard a unique feature

Preparing for the big fill of 100,000,000 cu. yd. with hydraulic dredges, and the decision to build them and all accessory floating plant on the job, introduced the unique spectacle of an active shipyard in northern Montana. The location of this yard and of the winter boat harbor is shown in the accompanying map, Fig. 2.

Activities in the boat yard, which began Jan. 10, 1934, included construction of 300 pipe-line pontoons, 200 power cable pontoons, four dredges (Fig. 8), four booster dredges, four work dredges, four loading barges, two derrick boats, two ferry boats and numerous anchor barges, elbow pontoons and skiffs. The work on an entire dredging unit was started at the same time, so that everything pertaining to one unit would be ready when needed. A unit consists of a dredge boat and a booster barge, each containing two 2,500-hp. motors driving 28-in. centrifugal pumps, then a land booster (Fig. 9) running on a track on a berm of the dam and containing a single 2,500-hp. motor and a 28-in. pump. Each dredge boat is equipped with a 115-ton suction ladder carrying an 8-ft. cutter head driven by a 700-hp. motor (Fig. 10).

The hull of the dredge boat is 40 ft. wide, 170 ft. long and 8 ft. 3 in. deep. It is provided with two steel spuds, 30 in. in diameter. Control of the variable dredge load is obtained by liquid rheostats similar to those used in steel rolling mills and on mine hoists. Two 10-ton traveling hoists were installed to lift the 22-ton, 2,500-hp. motors and 28-in. centrifugal pumps into place. About 15,200 lin.-ft. of 28-in. flanged steel pipe floated on pontoons, and 57,800 ft. of 28-in. land pipe will be on hand for the use of all four units at the start of the 1935 dredging season. The land pipe is ¼-in. steel having slip joints hooked together with hook and toggles and turnbuckles. During 1935 and 1936 it is proposed to dredge from the farthest parts of the borrowpits and to build up the dam on the flood plain, leaving the river channel open; then in 1937 it is planned to divert the river through the tunnels and close the gap in the river. Thus, during the first two

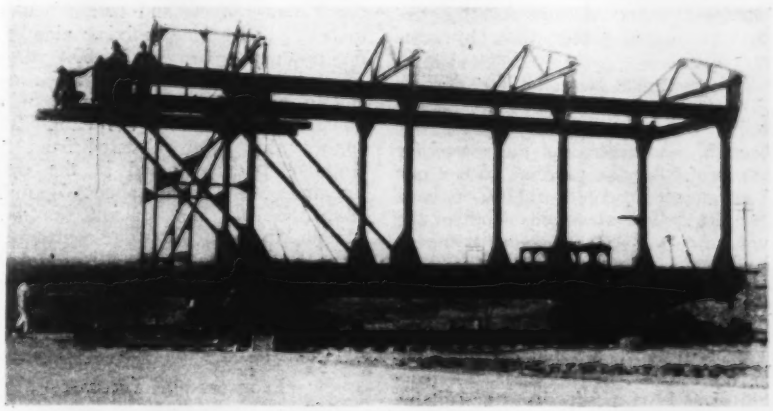


FIG. 9—PORTABLE CARRIAGE for a 28-in. booster pump, to be used along berms of dam and on slope for final placing of material on the higher lifts.

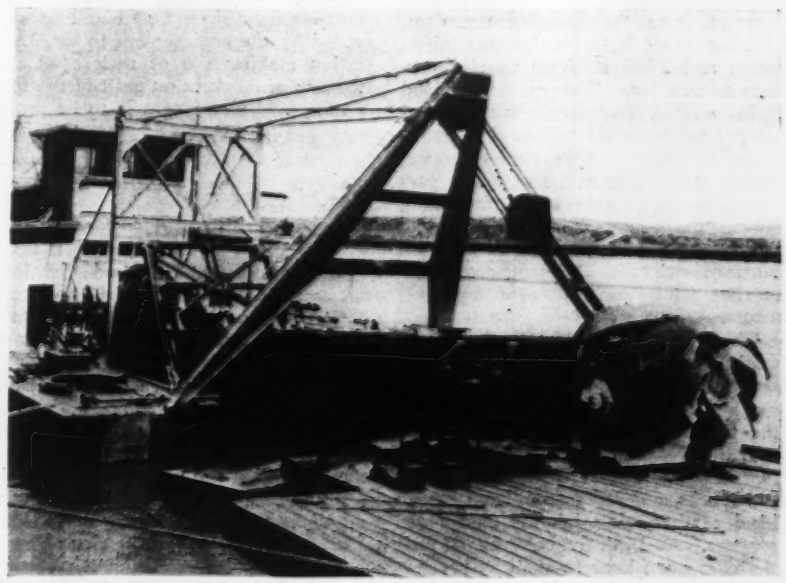


FIG. 10—BOW OF HYDRAULIC DREDGE for Fort Peck Dam, showing ladder boom, ladder and cutter head. Pumping is done by two 2,500-hp. electric motors driving a 28-in. centrifugal pump.

years, dredges can be interchanged between lower and upper borrowpits.

Dredge *A* was launched June 12, 1934, and the next day, the first booster barge followed. Low water made further launchings undesirable until November, by which time dredge *A* had been outfitted and started preliminary operations dredging a channel and a winter harbor. Digging started Oct. 11, ten months after the first keel beam was laid down. A procedure is being worked by which the materials are to be sorted out carefully, following the test drilling and laboratory analyses. The more impervious materials will be placed in the center core, and the more granular material will be deposited in the sides of the dam. An elaborate, well-equipped and well-staffed soil laboratory has been in operation making analyses from the test borings. The sorting methods and the necessity for quick changes in operation and in location are given as one of the main reasons for carrying out this work by government forces rather than by contract.

Five contracts were let for drilling 657 test holes with a total footage of 59,767 ft., of which 37,380 ft. was through overburden and the remainder was into shale. In addition, 25 test pits of an aggregate depth of 1,092 ft. have been dug. The maximum depth of the drill holes was 140 ft. More than 450 auger holes, averaging about 18 ft. deep, were put down. Test holes were spaced 200 ft. apart all over the base of the dam. After the stripping and grading had been done, 5-ft. holes were put down on 100-ft. centers so as to be certain of at least a 5-ft. depth of suitable material under all portions of the body of the dam.

More than 4,000,000 yd. of objectionable or unsuitable material has been stripped from the base of the dam, which extends 7,200 ft. between abutments and 2,875 ft. from upstream to downstream toe. The flat river flood plain, only a few feet above normal river level, consists of alluvium overlying the Bear Paw Shale in varying depths up to 150 ft. The lower portion contains a high percentage of sand, but at the top considerable clay and gumbo have been washed down from the adjacent hills. This finer material reaches depths of 20 ft. near the abutments.

The stripping contractors started work June 19, 1934, and completed the removal before the season closed in November. The general contractors and the several subcontractors employed, near the close of the work, three shovels, two draglines, nine elevating graders, 244 trucks and 769 men. This was an ideal earth-moving job for trucks and graders. As all of the bottom land near the dam must later be used as borrowpits for the dredges, it was necessary to haul the stripped material to the spoil areas an average of 7,500 ft. from the right bank and 9,000 ft. on the left bank. In the routine, the contractors aimed always to have trucks waiting behind the graders and to have the speed of the trucks regulated to 35 miles per hour. Due to the dryness of the season, the dust was a nuisance, and the roadways were constantly sprinkled and smoothed with bulldozers. No work was done at night with the elevating graders; nevertheless as high as 53,000 yd. and consistently over 40,000 yd. was moved per day. Addision-Miller, Inc., and Fielding and Shepley, Inc., were the general contractors.

Late in the fall, after some preliminary work was done by government forces, contracts were let for the spillway excavation of 13,000,000 cu. yd. of earth and shale. Part of the spillway channel, of varying width, is to be lined with a concrete slab. This spillway work will be under full swing in 1935 as well as the concrete lining and structures. The excavation will be prosecuted with shovels and trucks hauling to nearby draws. A mixing plant for the production of the 540,000 yd. of concrete will be installed at the discharge end of the spillway, 8 miles down the river from the dam. The spillway has been relocated from the tentative position noted in the early drawings, to a point about 3½ miles from the east abutment of the dam. Martin Wunderlich has one contract for 2,808,000 cu. yd. of excavation, and the Massman Construction Co. has contracted for the remaining 10,550,000 yd. of excavation and the placing of part of the concrete.

Progress and forecast

The year 1935 will see progress on every portion of the dam. Tunnel operations on the four pilots, all driven from the inlet portal, were 80 per cent complete on March 1 and will be succeeded by the enlargement to the 32-ft. section making use of rock saws and two sets of muckers on each of the four headings. Enlargement is to be prosecuted from the outlet end only. The first of the pilot tunnels was holed through on March 28, and the others followed within a few weeks.

Dredging is now under way, and it is planned to fill sections on either side of the river during the 1935 and 1936 seasons. The next year the river will be turned through the diversion tunnels, which are to be completed for the 1937 operations.

This past year has seen the completion of the town, four dredges and shipyard activities, stripping, 38 miles of railroad, including the Missouri River bridge and trestles, a complete mixing plant for the tunnels and portal structures, the 288-mile power line from Great Falls and the distribution system, an aggregate washing and screening plant at Cole, Mont., capable of producing 350 cars of sand and gravel per day, and full equipment and facilities for prosecuting every principal item in the construction of the project.

Employment records indicate that an unusually fast increase in payroll was effected at the beginning of operations, coming to a peak of 7,200 in midsummer of 1934. Approximately 5,000 have been on the payroll through the winter.

The Fort Peck Dam is being constructed under the supervision of the Corps of Engineers, Major T. B. Larkin, district engineer; Major Clark Kittrell, as chief of the operations division, has charge of all construction activities. Capt. J. B. Hughes is in charge of the administrative division. First Lieut. E. G. Plank is town manager and in charge of land acquisition. G. O. Evans, associate engineer, is chief of the general engineering division.

Plans for the project are prepared in the Kansas City, U. S. Engineers Office of the Missouri River Division under the supervision of Colonel R. C. Moore. Capt. Theodore Wyman, Jr., is assistant to Colonel Moore. A staff of consultants includes Thaddeus Merriman, Louis C. Hill, D. C. Henny, William Gerig, and Warren J. Mead.

Regional Planning Progress in the Northwest

THE PROGRESS made in local and regional planning in the states of the Northwest is indicated by a statement in the recently issued progress report of the Pacific Northwest Regional Planning Commission, to the effect that in the four states concerned (Montana, Idaho, Oregon and Washington) 66 per cent of the total area and 75 per cent of the population are now under the jurisdiction of a city or county planning commission. At the beginning of 1934 the four states had only eight city planning bodies and not a single county planning commission. At present 111 of the 175 counties in the four states have organized such commissions, as well as 41 of the 92 cities of more than 1,000 population. In addition, 18 cities of less than 1,000 population have planning commissions. District planning has been developed extensively in Montana, which has been divided into twelve planning districts, with a district chairman and a planning board, the latter made up of members representing the component counties.

For the present the greatest need in the planning field in this region appears to be the collection of comprehensive survey data, "including cover, topography, surface and groundwaters, geology, land and soil, minerals, population, industries and markets."

Aerodynamics and the Civil Engineer—VI

Engineering Meteorology

A review of the science of air movements as it applies to the civil engineer's problem of designing structures to resist wind forces

By W. Watters Pagon
Consulting Engineer, Baltimore, Md.

THIS SERIES OF ARTICLES, to date, has advanced from a general presentation of those aerodynamic theories and facts that affect civil engineering practices (*ENR*, March 15, 1934, p. 348) to consideration of such special questions and studies as correction of smoke-stack vibrations (*ENR*, July 12, 1934, p. 41), wind-tunnel studies of bridge models (*ENR*, Oct. 11, 1934, p. 456), and wind-tunnel studies of building models (*ENR*, Dec. 27, p. 814), and finally to an explanation of the action and effect of eddies and turbulence (*ENR*, April 25, 1935, p. 582), which in actual practice modify all theories and results based on ideal air flow. The accompanying article on meteorology will be followed soon by the seventh article of the series, which will be devoted to the subject of variation of wind velocity with height. —EDITOR.

KNOWLEDGE of certain aspects of the science of meteorology is indispensable to the civil engineer. The origin of air currents and the effect of temperature, earth rotation, friction and altitude comprise a portion of this knowledge. The movement, frequency and character of storms of various kinds are also basic information for the engineer who designs structures subject to wind forces, just as rainfall and run-off are basic for the hydraulic engineer. This article discusses some of these meteorological data from the standpoint of their practicability for the civil engineer. The writer is indebted to John R. Weeks, of the Baltimore Weather Bureau station, for helpful suggestions and criticisms.

Temperature and air currents

The source of the winds with which the engineer deals is of course the sun's energy. Insolation—the heating effect of the sun's rays measured at the earth's surface—represents the heat that has penetrated the atmosphere. Considering cloudiness and other factors, less than one-half the solar heat reaches the surface. The atmosphere reflects, absorbs and re-radiates some, the earth absorbs and reflects the remainder, such surfaces as water, ice, snow, white minerals, etc., reflecting a larger amount, and black, brown or vegetation-covered fields, a lesser amount.

Throughout the year the earth's surface as a whole does not gain in temperature, hence it must re-radiate all absorbed heat. Different areas, even only a few feet apart, having differing absorption, radiate differently to the adjacent air during the course of the day; for example, a green field next to one of stubble, or land next to water, will cause serious bumps to an airplane flying over them. These bumps indicate differential vertical velocity. The earth's radiations are more readily absorbed by the atmosphere than those of the sun because they are of shorter wave length, and about two-thirds of this heat is absorbed by the water vapor in the air.

Alterations in the density of the air by heating cause vertical movements to re-establish equilibrium, resulting in horizontal movements which we know as wind. If a vertically moving mass of dry air neither gains nor loses heat from the surrounding atmosphere—i.e. moves adiabatically—then the rate of temperature loss (the *lapse rate*) with height is about 5½ deg. F. per 1,000 ft. The maximum lapse rate that is physically possible is 19 deg. F. per 1,000 ft., which can only occur for a constant air density regardless of height. If the lapse rate were greater, the density would increase and the air stratification would immediately overturn.

When a rising mass meets a condition whereby the moisture is precipitated as rain, the heat contained in the water vapor is transferred to the air, increasing the convection, as may be observed in a thunderstorm.

By Archimedes' principle, if a given air mass is of different density than that of the surrounding air, it will rise or settle according to the difference of density and, therefore, according to the difference of temperature. If relatively warmer, it will rise, and vice versa. If the lapse rate in the atmosphere is less than the dry adiabatic rate (as it usually is), then a mass of air pushed upward for any reason (and cooling very nearly at the dry adiabatic lapse rate, regardless of the humidity) will become cooler and therefore denser than its surroundings, and will attempt to settle back again; if depressed, it will become warmer and lighter, and will attempt to rise again. The condition with atmospheric lapse rate less than the dry adiabatic is called stable equilibrium. If the atmospheric lapse rate is greater than dry adiabatic, the displaced air will be accelerated and will move farther, and this condition is called unstable equilibrium.

If the rising air mass is saturated, the saturation adiabatic lapse rate dictates its decline in temperature. This rate is less than that for dry air, because part of the cooling effect is required for the condensation of the water vapor; it is also variable with height, as the water vapor varies. For a surface temperature of 70 deg. F. it is about 2½ deg. F. per 1,000 ft. and changes about ½ deg. for each 10 deg. F. change in temperature, being less for increasing temperature and vice versa.

If the lapse rate in the atmosphere lies between the dry and saturation adiabatic rates, the atmosphere is in stable equilibrium. But a rising saturated mass starting at the temperature of its surroundings must, when condensation occurs, continually become warmer than the adjacent air and must continue to rise until rain occurs, when lower masses may be cooled by falling rain. The atmosphere is not stable for saturated air, which has been raised to such an elevation that its temperature is at all in excess of its surroundings.

In the first 1,000 ft. the mean normal summer lapse rate is about 3½ deg. F. per 1,000 ft., or greater than the saturation adiabatic rate and slightly more than one-half the dry adiabatic rate. In winter it is only about 1 deg. F. per 1,000 ft. This indicates thermal stratification such that an air mass will in general, and more especially in winter, continue in horizontal motion unless forced to another elevation. Local convection currents as in a thunderstorm may of course result from local insolation, and general storms are aided and tropical storms may be maintained by the condensation aloft of the water vapor from near the surface. From day to day the lapse rate in the atmosphere is very irregular, varying from an increase with altitude—inversion—to slightly above the dry adiabatic rate. Inversion occurs only for brief periods and short height ranges, or at night due to radiation, or due to the overrunning of hot air or underrunning of cold air.

Gradient velocities and isobars

The wind in movement over the earth's surface is deflected to the right (in the northern hemisphere) because of the earth's rotation. The barometric gradient, equivalent to the deflective effect, is $dp/dn = 2\rho\omega v \sin\lambda = \rho Vl$; where dp is the pressure change in dynes per sq.cm. in a horizontal distance dn

between isobars (measured normally); ρ is the density in grams per cu.cm., ω is the angular velocity of the earth's rotation $= 2\pi/86{,}164$, and λ is the latitude. In this equation $l = 2\ \omega\sin\lambda$.

If an air current has a constant speed, G, in a circle of radius, r, there is a centrifugal force of $\rho G^2/r$. For constant velocity, neglecting friction for the present, $\pm\rho G^2/r + \rho Gl =$ pressure gradient, where the plus sign applies (in the northern hemisphere) to cyclonic (counterclockwise) areas, and the minus sign to anti-cyclonic (clockwise) areas. Solving:

$$G = +\sqrt{\tfrac{1}{4}r^2l^2 + \frac{r\,dp}{\rho\,dn}} - \tfrac{1}{2}rl$$

for cyclonic areas.

$$G = -\sqrt{\tfrac{1}{4}r^2l^2 - \frac{r\,dp}{\rho\,dn}} + \tfrac{1}{2}rl$$

for anti-cyclonic areas.

$$G = \left(\frac{dp}{dn}\right) \div \rho l \text{ for straight isobars.}$$

G is in cm. per sec., and r in cm. These velocities, G, are called "gradient velocities."

Since deflection is toward the right (looking *with* the flow), there must be higher pressure on the right, to maintain uniform flow. In cyclonic storms in the northern hemisphere the wind direction is counterclockwise, hence there must be low pressure at the center —i.e., the pressure gradient is centripetal and opposed both to the centrifugal force and to the deflective force. In anti-cyclonic areas though, the pressure gradient must be centrifugal, acting with the centrifugal force against the deflective force.

The effect of friction is considered separately, but it has been observed that not until an altitude of about 1,500 ft. is reached, on the average, are gradient velocities met.

Converting into English units, with dp/dn expressed as 0.1 in. of mercury in N miles spacing of isobars (i.e. for isobars plotted for 30.0, 29.9, 29.8 in., etc.), N being measured normal to the isobars, with $\rho = .0738 \div 32.2 = .00229$ at 1,500 ft. r in miles, G in m.p.h., latitude 40 deg:

$$G = 0.169r\left(\sqrt{1 + \frac{49100}{Nr}} - 1\right)$$

for cyclonic areas.

$$G = -0.169r\left(\sqrt{1 - \frac{49100}{Nr}} + 1\right)$$

for anti-cyclonic areas.

$G = 4260/N$ for straight isobars.

Some typical gradient velocities are given in Table I.

If two extensive currents pass, each having low pressure on its left side due to rotation of the earth, they will enclose low or high pressure according as they pass to the right or left of each other. In the first case, if one is colder and more dense, the denser air will lie closer to the surface, underrunning the warmer air, with a flatly inclined surface of discontinuity between them. In this type of mechanically juxtaposed currents are produced most of the cyclonic storms that pass over the United States.

TABLE I—GRADIENT VELOCITY IN M.P.H. FOR CYCLONIC STORMS

Lat. 40° N, El. 1,500 Ft.

Spacing of Isobars N, Miles	Radius of Isobars, r, in Miles 60	300	600
800	5	5	6
400	8	10	10
250	11	14	15
200	13	18	19
150	16	23	25
100	20	33	36
80	24	38	44
60	28	48	56
50	32	54	63
40	37	64	75

The tendency to flow parallel to the isobars is not realized near the earth's surface due to friction. At sea the average angle of deviation is about 10 to 20 deg., but on land the hills, trees, buildings, etc., may cause an angle as great as 45 deg. The wind therefore blows *into* cyclonic storm areas, and *out of* anti-cyclonic areas, as it rotates around them.

Prevailing winds

Across the United States there is a gradient toward the north. At about 2 miles elevation the isobars (equal pressure lines) follow the Gulf Coast and a line from Wisconsin to New Hampshire, with fanlike spacing between. In summer the pressure decrease northward is about 0.2 in. of mercury, and in winter about 0.9 in., in 1,100 miles.

Without rotation of the earth, the wind aloft (in the U. S.) would blow from the equator toward the poles, because of this poleward gradient. But because of the deflecting effect, the prevailing winds are westerly. In winter and at higher altitudes they are better developed. Large land areas exert a strong modifying influence. Ward has plotted the July surface winds as originating in the Gulf and flowing fanwise to northwest, north and northeast, the Mississippi River being a rough dividing line between those with east and west components. These winds are associated with much of the hot summer weather. A line from New Orleans to Chesapeake Bay and another from Corpus Christi to eastern Montana give about the center lines of these areas and their respective angularity. In January, a line from Montana to St. Louis forms about the center line of the northwesterly winter winds, and this bends so as to lie coincident with the Ohio River, finally curving toward the Atlantic Coast.

Meteorologists have originated terms and methods for measuring air and air currents. Since 1805 Admiral Beaufort's scale of velocity has been much used (Table II).

The National Advisory Committee for Aeronautics in 1922 adopted a "standard atmosphere" for the United States, which applies to latitude 40 deg. N. and is an average for the whole country. It is given in Table III for the range from sea level to 10,000 ft.

Storms

Some discussion of the storms that pass over the country, of the polar front theory of Bjerknes and of general atmospheric circulation may be helpful. Heated air rising at the equator largely settles again south of the United States as it cools, causing the high-pressure area there. Some, however, moves poleward and settles, producing a polar excess. There is also a polar circulation, similar to the trade winds, caused by cold air settling at the pole, moving southward, rising when warmed, and returning to the pole. This is accompanied by a pressure gradient southward, opposed to the northward gradient across the United States. Due to the earth's rotation, therefore, there are easterly subpolar winds and westerlies just to the south of them, with a trough of low pressure between, and a discontinuity surface near the Canadian border. But the excess of polar air must find a southern outlet, opposed by the pressure gradient against it. Seemingly this excess breaks through intermittently, the process being more vigorous in winter, resulting in "cold

TABLE II—BEAUFORT'S WIND-VELOCITY SCALE

Beaufort No.	Explanation	Descriptive Conditions: Marine	Descriptive Conditions: Land	Statute, M.P.H.	Weather Bureau Terminology
0	Calm		Smoke rises vertically.	0–1	
1	Light air		Smoke drifts, weather-vanes quiet.	1–3	Light
2	Slight breeze	Sufficient wind for working ship.	Felt on face, leaves rustle, vanes moved.	4–7	
3	Gentle breeze		Leaves and twigs in motion; extends light flag.	8–12	Gentle
4	Moderate breeze	Most advantageous for sailing, leading wind, all sail.	Raises dust and paper; moves small branches.	13–18	Moderate
5	Fresh breeze		Small trees in leaf sway, crested wavelets on inland waters.	19–24	Fresh
6	Strong breeze		Large branches moved; wires sing; umbrellas difficult to handle.	25–31	Strong
7	High wind	Reduction of sail necessary with leading wind.	Trees move, inconvenient to walk.	32–38	
8	Gale	Considerable reduction of sail necessary with quartering wind.	Breaks trigs; impedes progress generally.	39–46	Gale
9	Strong gale		Slight structural damage occurs.	47–54	
10	Whole gale	Close-reefed sail running, or hove to under storm sail.	Rare inland; trees uprooted; considerable structural damage.	55–63	Whole gale
11	Storm		Rare; widespread damage.	64–75	
12	Hurricane	No sail can stand even running.		75	Hurricane

TABLE III—CHARACTERISTICS OF STANDARD ATMOSPHERE

(Average Air and Vapor Pressures, Temperatures and Weights at about Latitude 40°N. in the United States)

Altitude Above Sea Level, Ft.	Summer				Winter				Annual (also Spring and Autumn*)			
	Pressure in. Hg.	Temperature, Deg. F.	Vapor Pressure in. Hg	Weight, Lb./1,000 Cu. Ft.	Pressure in. Hg	Temperature, Deg. F.	Vapor Pressure in. Hg	Weight, Lb./1,000 Cu. Ft.	Pressure in. Hg	Temperature, Deg. F.	Vapor Pressure in. Hg	Weight, Lb./1,000 Cu. Ft.
0	29.94	77.0	0.65	73.4	30.12	28.5	0.13	81.7	30.03	52.5	0.34	77.4
1000	28.92	73.5	0.57	71.4	28.99	27.5	0.11	78.8	28.95	50.5	0.30	75.0
2000	27.92	70.5	0.50	69.4	27.89	26.5	0.10	76.0	27.91	48.5	0.27	72.6
3000	26.95	67.0	0.43	67.4	26.84	26.5	0.09	73.1	26.90	47.0	0.25	70.2
4000	26.01	64.0	0.37	65.5	25.82	26.0	0.08	70.4	25.93	45.0	0.20	67.9
5000	25.10	60.5	0.32	63.7	24.84	24.5	0.07	67.9	24.98	42.5	0.18	65.8
6000	24.22	57.0	0.27	61.9	23.90	23.5	0.06	65.5	24.07	40.5	0.16	63.7
7000	23.55	54.0	0.23	60.0	22.99	22.0	0.06	63.2	23.18	38.0	0.14	61.6
8000	22.52	50.5	0.20	58.3	22.12	20.0	0.06	61.1	22.33	35.0	0.12	59.7
9000	21.71	47.5	0.17	56.6	21.27	17.5	0.05	59.1	21.50	32.5	0.11	57.8
10000	20.92	44.0	0.15	54.9	20.45	15.5	0.04	57.0	20.70	29.5	0.09	56.0

*Approximately.

waves," comprising anti-cyclones with associated cyclonic areas.

The continental mass of North America, extensively snow-covered in winter, seems to offer opportunity for a salient in the discontinuity surface. According to Bjerknes and Exner there develops a wave motion in this surface, and at times a southward surge of a mass of cold air across the path of the westerlies; because it is colder it tends to underrun them. Something similar to this may be seen where a muddy tributary slowly enters a clear river, forming repeated muddy eddies that slowly diverge in the clearer water. In such a condition the discontinuity surface is vertical because the densities are equal; but that between a cold air and a warm air is nearly horizontal, having a slope between 1:50 and 1:200.

How the anti-cyclone and the cyclone develop is not clearly known, but that they follow each other intermittently, especially in winter, is common knowledge. They move (roughly) along the trough of low pressure.

The easterly front, called the *cold front*, of a cold mass that has been projected into the United States is of interest to engineers. Moving southward and then eastward, and being denser, it underruns the warmer air, lifting it off the ground. The warmer air with its more considerable moisture cools adiabatically to the point of condensation, when clouds appear and rain falls. Hence, preceding the arrival of the cold front at a ground station, there may be bad weather. Near the ground, friction retards the spreading cold air, causing the upper portion to overtravel like a breaker on a beach at the plunge point. And like the breaker, this effect takes place all along the 100 or more miles of cold front, resulting in the *line squall*, which has caused so many aircraft disasters. These effects can be seen in the cloud formations under favorable circumstances.

Preceding the line squall, the warmer air of less density records itself by a lowered barometer. As the squall cloud passes there is a sudden transition to cold, denser air piled up in a roller so that immediately the barometer rises, and soon thereafter the temperature at the ground drops. As soon as the rising moist air has had the moisture shrunk out of it, the sky clears, and the wind is from the west or northwest.

Wind velocities in a line squall are high, and turbulence is great. This is due to the instability caused by abnormally cold air having overrun the warm air that has been held back by ground friction, and results from the overturning of this stratification. To support a 2½-in. hail stone (about the largest recorded) for a time sufficient to congeal its successive layers of ice, requires vertical velocities of perhaps 120 ft. per sec., and in the thunderstorms that usually attend line storms these velocities may extend aloft to heights of 15,000 ft. or more. The horizontal speed of advance of the line squall may be from 25 to 60 m.p.h., and the horizontal wind velocities may be from 15 to 100 m.p.h., although velocities above 40 m.p.h. are rare. Reference may be made to the records of vertical velocities in the line squalls in which the Shenandoah and the Akron were destroyed. A glider record as great as 8,000 ft. has been made in Europe by a flyer who kept his machine in and near thunder and cumulus clouds, being raised bodily by the vertical air currents. The "roll cloud" precedes (at the ground surface) the line of wind shift by perhaps 4 to 5 miles, which means 8 to 10 min. if the speed of advance of the squall is 30 m.p.h. In the Atlantic and Gulf states typical roll clouds are infrequent.

In the cyclonic area, which carries in advance of it a "warm front," the wind blows inward from all directions but (due to the effect of friction) at angles of 20 to 40 deg. to the isobars instead of parallel to them. Nearly half of these storms reach the United States from the Province of Alberta, many of them being offshoots of the Aleutian "LOW"; a small per cent originate in the Gulf and South Atlantic and a few in the Pacific and in the Rockies. Bowie and Weightman estimate an annual average of 124 such storms, of which about 60 per cent occur in summer. The general path is eastward, leaving via New England, and the average rate of travel is 550 to 650 miles per day, or about 25 m.p.h. They generally follow the direction of the winds at about 2 miles altitude.

The tropical storms commonly called hurricanes are generally much smaller, have much steeper gradients and much lower center pressures. They develop from June to November, but mostly in August to October, and originate west of the Azores. The 50-year seasonal average is 6. One such storm affects the United States in two to three years, and they either move inland over the Gulf or Florida Coast (and rapidly decrease in intensity), or swerve to the northeast and follow the Atlantic Coast. Those in the latter class grow rapidly in size and diminish in intensity at higher latitudes, and later may become the same as the extratropical cyclonic storms, some even traveling to the Mediterranean before dissipation. Thus their greatest effect is confined to the Gulf states. The storm of August, 1933, caused high winds, rains and tides in the Middle Atlantic States as it passed inland.

Anti-cyclonic areas are the inverse, in that the winds blow outward, at times at 90 deg. to the isobars. Because they bring clear cold weather they frequently cause cold waves. Their diameter is larger, 700 to 2,500 miles, and they follow generally a path eastward or southeastward, often joining the Bermuda "HIGH" or passing out over the Gulf or Middle Atlantic states.

Tornadoes occur principally in the Mississippi and Ohio River valleys, and in the spring and summer, but minor storms of this character have occurred on the Atlantic Coast, and water spouts are sometimes seen in the same region but do not have the violence of tornadoes. Tornadoes have high velocities and extremely low—almost explosive—center pressures, but are only 300 to 1,600 ft. in diameter in the destructive portion. (See article on eddies, *ENR*, April 25, 1935, p. 582.)

Thunderstorms are of three types. The common summer type results from rapidly rising warm air currents due to local heating of the air. The line storm type in the "cold front" is due to the mechanical uplift of warm moist air by underrunning cold, heavy, dry air whenever the lapse rate is such as to cause instability. In the summer type, the wind, preceding the storm is toward the cloud; then comes the advancing dust squall, and finally the rain. High vertical velocities are experienced, and horizontal velocities are often such as to cause structural damage. The squall wind is due to the rapid descent

TABLE IV—INDICATED AND TRUE SPEEDS FOR ROBINSON CUP ANEMOMETERS, AND STAGNATION PRESSURES CORRESPONDING

Indicated Wind Speed 3-cup M.P.H	4-cup M.P.H.	True Wind Speed M.P.H.	Stagnation Pressure q, (Lb.)/Sq.Ft.
5	5	5	0.064
10	11	10	0.256
15	17	15	0.575
20	23	20	1.023
25	30	25	1.600
31	37	30	2.302
36	44	35	3.133
41	50	40	4.092
47	57	45	5.179
52	64	50	6.394
57	71	55	7.737
63	78	60	9.208
68	85	65	10.81
73	91	70	12.53
79	98	75	14.39
84	105	80	16.37
89	112	85	18.48
95	118	90	20.72
100	125	95	23.08
105	132	100	25.58
111	138	105	28.20
116	145	110	30.95

of rain and cooled air within the storm, the air spreading outward over the ground with lowered velocity. The number of thunderstorm days is greatest on the Gulf Coast, at about 90 per year, diminishing to about 20 at the Canadian border and the Rockies, except a small peak of 70 in New Mexico. Toward the Pacific Coast the number diminishes to about 5. Some days have two or more storms; hence the frequency of storms exceeds these figures. They are usually of a local nature, but also prevail at many places simultaneously in the lower quadrants of a cyclonic storm or along a line squall.

True velocities

The true velocity for a given observed velocity differs materially with the type of anemometer used for recording. The 4-cup Robinson anemometer was used by the Weather Bureau prior to Jan. 1, 1928, and the 3-cup from then until Dec. 31, 1931, since when true velocities have been published. Table IV gives the relationship, and also the stop or stagnation pressures, based on $q = \frac{1}{2}\rho V^2 = 0.001189v^2$ for v in f.p.s., and $0.002558V^2$ for V in m.p.h., at 59 deg. F. and 29.9 in. of mercury.

The Weather Bureau usually records the average velocity for 5-min. intervals and the average extreme for 1 min. as recorded by a cup anemometer. In our present state of knowledge we must assume that in gusts the recorded true velocity is increased by 25 to 50 per cent.

Frequency of high winds

There is a serious lack of recorded data on the frequency with which winds of various velocities occur. Clearly the frequency of occurrence in any locality is a function of the frequency of highs, lows and thunderstorms, and also of the pressure gradients in or between cyclonic and anti-cyclonic areas. Stations lying in the path frequented by these areas have a greater chance of high steady winds, while other areas may be subject to thunder squalls as in the tropics. In areas where tornadoes occur there is the chance of high velocity, but, for a given station, the number of repetitions has been small. The common high short period velocities (around 50 m.p.h.) occur in thunder squalls.

Van Orman has made an illuminating study of velocities near the Atlantic Ocean and at the cities of Philadelphia, Baltimore, Washington and Richmond, in determining the most suitable site for the proposed Goodyear-Zeppelin terminal, to be established in this country. He shows the lessening of average velocity from the Coast to these cities, partly due to increased friction of land as against water. Similarly, Nantucket Island and Cape Hatteras show average yearly velocities about 40 per cent higher than other Coast points because of their exposed position.

The writer made a brief study some years ago of the frequency of winds recorded in Baltimore. It appears that if Y is the period of recurrence of a given 5-min. velocity—i.e., the interval in years in which such velocity will be recorded once for a 5-min. period by the Weather Bureau, then the velocity is $V = 42 + 14 \log Y$, in m.p.h., where the logarithm is to base 10. If now it is considered that in gusts the velocity is increased 50 per cent and that the pressure on *square flat plates* is $0.0033V^2$ (*ENR*, March 15, 1934), then $p = 0.0074\ (42 + 14 \log Y)^2$ in lb. per sq.ft. at 215-ft. elevation, in a 50 per cent gust. The data upon which this is predicated are most unsatisfactory because the anemometer was located at 8 different points in Baltimore in 61 years, and the longest record at any one station was 18 years. The exposures differed, and the heights above ground and sea-level differed. It was necessary to adjust the several sets of records by crude methods, so that the formula does not bear critical analysis. Moreover, the Weather Bureau ran simultaneous records at the last two stations for eight months, but the correlation factors varied with every point of the compass from 0.45 for NW to 0.75 for NE, because of interferences in the old exposure.

Wing has given in *Proceedings*, Am.Soc.C.E., some excellent data of this sort, plotted however on probability paper. It would be most helpful if an engineer in each locality would cooperate with the local weather bureau station, to collate similar data. Conditions like those at Baltimore are common to anemometer exposure, the whole comprising a difficult practical problem.

From this formula the probable velocities at Baltimore would be as shown in Table V.

Since the record covered only 61 years, any values for Y greater than 60 are purely hypothetical and obtained by extrapolation. There was one of 70 m.p.h. at $Y = 21$; 72 at 31; and 75 at 61; which lie 8 to 10 m.p.h. above the curve, but they are as yet only single occurrences.

Progressive growth of neighboring buildings may have a marked effect on the recorded velocities, and Harris has made a study at the Bureau of Standards and at Pennsylvania State College on the effect of interference on a model of the Empire State Building. Of course anemometer readings should be corrected to true velocities, according to the table of true speeds, care being taken to ascertain the type of instrument, whether 3-cup or 4-cup.

It will be noted that while 20 lb. per sq.ft. assumed design pressure is exceeded once every seven years, nevertheless the logarithmic variation is such that in 40 years the pressure is only 50 per cent in excess of it, and in 100 years only eighty per cent.

It would appear that a design load of 20 lb. per sq.ft. for low buildings in the vicinity of Baltimore would be a safe one, if the building face is nearly square; but there is always a possibility that tomorrow a tropical hurricane moving northeasterly along the Atlantic Coast may be deflected somewhat inland, causing higher velocities than may have previously been recorded, as was the case with the August, 1933, storm. Attention is also called to the fact that the factor 0.0033 applies fairly only to large square surfaces fully exposed to the wind; but in *ENR*, March 15, 1934, it was shown that for a long narrow plate the pressure is about 56 per cent higher, and in a later article it will be shown that there is considerable increase in velocity with height above the ground, which must be taken into account for high buildings. A tall narrow building in Baltimore would therefore require an additional 10 lb. per sq.ft. because of its shape, and an additional amount because of its height, so that 30 lb. per sq.ft. seems to be correct as a *minimum*. On the other hand, low buildings may be much sheltered by adjacent structures, so that they are subjected to little wind; and vice versa, even low buildings that are so aligned that they receive the wind spilled off from an adjacent high one may be subjected to quite high velocities, as anyone knows who has watched from a high window the action of rain in a high wind, showing the spilling of the wind.

TABLE V—PROBABLE TRUE VELOCITIES AT BALTIMORE, 5 MIN. PERIODS AND IN GUSTS (50%) AT ELEVATION 215 FT.

Y, years	1	2	3	5	8	10	20	50	75	100
V, m.p.h., 5-min	42	46	49	51	55	56	60	66	68	70
V, m.p.h., gusts	63	69	74	76	82	84	90	99	102	105
p, lb. per sq.ft	13.1	15.7	18.1	19.1	22.1	23.3	26.8	32.3	34.3	36.3

Dust Storms: Their Cause and Suggested Remedies

Drought and inadvisable farming methods have subjected 18,000,000 acres to wind erosion—Although more extensive than previously, current dust storms are not unprecedented in severity—Rain and changed methods of cultivation will save most of the areas

By R. I. Throckmorton
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SENSATIONAL REPORTS and news pictures which apparently substantiate them appear in the nation's press almost daily predicting the devastation of the Great Plains by wind erosion. They imply that vast areas of farmland must be retired from cultivation, that population may have to be shifted, that towns may have to be abandoned or face a permanent depression. Unquestionably the conditions which give rise to such reports have civil engineering significance. What are these conditions? Are the reports exaggerated? What measures are advisable to stop current wind erosion and stabilize the soil permanently? At the request of *Engineering News-Record*, Professor Throckmorton, agricultural expert and intimately associated with the Great Plains problem, has supplied the answers to these and other questions. His analysis, presented herewith, while verifying the seriousness and severity of the dust storms, does not admit that anything like devastation of vast areas is imminent. Though more widespread than ever before, this season's wind erosion is not of unprecedented severity. Only small areas have been permanently impaired. An end to the prolonged drought and institution of farming practices that take account of the annual occurrence of high winds will restore and stabilize the Great Plains, and make living both tolerable and profitable, he concludes. —EDITOR.

SOIL EROSION by wind has been the most severe in history in the western portion of the Great Plains this year because of the unprecedented drought and the physical condition of the soil, which made conditions ideal for soil blowing. But it has been severe primarily because of the vast region over which it has extended and because of its duration rather than the degree to which it has taken place in any given locality.

The area over which wind erosion is taking place this year includes north-central and western Kansas, eastern Colorado, eastern New Mexico and the panhandles and adjoining territory of Oklahoma and Texas. There are about 18,000,000 acres of land within this area that are being eroded by wind or are subject to such erosion. Throughout the entire region there is practically no green vegetation, which condition, however, is due primarily to lack of moisture rather than to soil blowing.

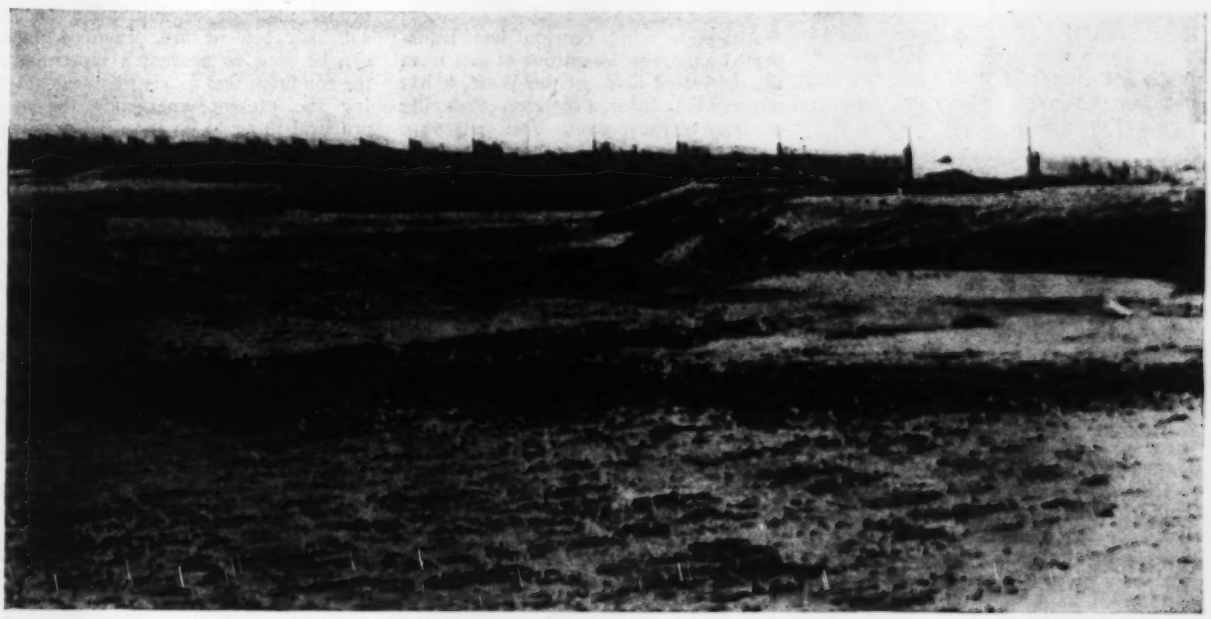
During periods of soil blowing in the past, conditions have been just as severe in local areas as they have been this year, but they received only limited attention. The fact that climatic and soil conditions have been favorable this year for the formation of great clouds of dust to be carried by the wind for hundreds of miles and that erosion has taken place over a wide area have made the situation spectacular.

It is difficult for a person who has never experienced a dust storm to realize the effect it has on living conditions. The air becomes saturated with particles of soil so fine that they penetrate into every corner of the most modern building. It is impossible to keep them out of the home, although windows are kept closed day and night. Breathing becomes difficult, and the eyes and nostrils become inflamed. During the most severe storms visibility may be reduced to a few feet for a short period of time.

One of the most serious effects of the storms is their influence on the surroundings and living conditions of the people and of livestock. Yet, although living conditions have been severe and the people have withstood many hardships, only a few of them have left the region. Those who have moved away are primarily tenant farmers who left as soon as they learned they would not have a crop of wheat this year.

Soils left exposed to wind

The severe wind erosion of soils in the Great Plains in 1934 and again in 1935 has been caused by a combination of conditions that may or may not occur again over such a wide territory. There is no doubt but that such conditions will reoccur relatively frequently



TYPICAL wind erosion of soil. View shows a field of drought-dried wheat stubble from which fine cultivated soil has been blown, forming dunes against a snow fence.

in local areas. The drought of the last few years and especially the low precipitation of 1934 made it impossible for vegetation to become established on much of this land, and the soils were therefore left exposed. The long periods of drought and the cultivation that was practiced in an attempt to grow crops pulverized the surface soil in many sections until it became dust-like in structure.

Deficiency of rainfall

The severity of the drought is illustrated by some of the rainfall records for the region.

At Dodge City, Kan., the normal precipitation over a period of 50 years is 20.5 in., but for the four-year period of 1931-34 inclusive the average was 15.9 in. At the same location the normal precipitation from July 1 to March 1 is 11.5 in., but from July 1, 1934, to March 1, 1935, it was only 6.5 in.

At Garden City, Kan., the annual rainfall for a period of 41 years averages 19.5 in.; for the last four years it was only 15.5 in. The normal rainfall at this station from July 1 to March 1 is 10.8 in., but during the eight months to March 1, 1935, it was only 4.5 in., or less than half of normal.

The annual rainfall at Tribune, Kan., is 16.6 in., but for the four-year period under consideration it averaged only 13.5 in.; the eight-month normal, July to March, is 8.7 in., but this year it was only 3.7 in. The annual rainfall at Colby, Kan., normally is 18.4 in., but for the past four years it was only 14.5 in., while the eight-month precipitation from July to March last was only 3.9 in., compared with a normal of 9.8 in.

This lack of rainfall during the latter half of 1934 made it impossible to secure stands of winter wheat over much of this region last fall. Because of a lack of moisture a high per cent of the wheat died during the winter in those sections where there was sufficient moisture for the establishment of stands last fall but not enough reserve to meet the requirements of the plants.

Farming practices

Shortage of feed for livestock last year because of the failure of feed crops and the poor condition of the pastures made it necessary for farmers to use all available materials for feed. Wheat stubble, corn stalks, sorghum stalks and even weeds were either pastured close to the ground or were harvested so close as to leave little or no protection for the soil. This condition caused great areas of soil to be exposed to the action of wind.

Under normal conditions much of the land that was bare would have been listed during the late fall or winter. This year, however, the farmer's resources were so low that he felt he could not afford to do any more cultivating of his land than was absolutely necessary; he was conserving his funds until time to plant some spring crop. The drought continued during the winter and early spring; there was not enough moisture to justify the seeding of barley and oats, and the soil remained smooth, fine and without cover. The farmer continued to conserve his resources for the planting of corn and the sorghums, but wind erosion started during March, long before the time of planting these crops.

The methods that have been used in cultivating these soils during the past have also tended to make them more subject to erosion by wind. The common practice has been to cultivate shallow with the disk types of implements, and to cultivate when the soil was too dry. Under such conditions implements of disk type pulverize the soil, destroy the clods and leave a fine surface layer. The use of such implements as the lister, spring-tooth harrow and duckfoot cultivator will cause the coarse cloddy material to be left on the surface and thus establish a condition that tends to prevent erosion.

The expansion of the area under cultivation during and following the World War, in response to the demand for an increased production of food crops, resulted in the breaking of land that should have been left in native sod. This is especially true in some of the the more sandy regions and in other areas of light rainfall. The breaking of such lands added to the acreage that is being eroded by wind; but if such areas had not been broken, there would still be dust storms this year, because some of the worst erosion has taken place in regions that normally have sufficient rainfall for successful crop production practically every year.

Land still fertile

Although wind erosion has transported enormous quantities of soil from the cultivated fields of the West, it has not seriously injured the crop-producing capacity of the region. The soils have been permanently reduced in productivity only in local areas, as on the more exposed spots and in some of the sandy regions. In the remainder of this vast territory the actual removal of soil from the fields has been very slight. The condition of the atmosphere when it is heavily laden with dust may cause one to think that all of the surface soil is being removed, but this is far from the actual condition. The same layer of dust may be carried back and forth by alternating winds from the north and south and thus keep the air full of dust for several days without any material increase in the amount of soil that has been eroded from the fields. The total amount of soil that has been removed from most fields by wind erosion this spring is less than the amount that is frequently removed from some of the rolling cultivated lands farther east during one heavy rain storm.

The statements that the Great Plains will soon be a desert of drifting sand are without foundation. In the first place, desert conditions could not exist in this region without first having a tremendous change in climatic conditions, and there is nothing to indicate that the climate of the region will change radically within a short period of time. In the second place, sand dunes are not common throughout most of this region, and therefore drifting dunes of sand could not exist.

With the exception of the local areas that have been mentioned, the soils of the Central West will again produce good yields of adapted crops as soon as they have been cultivated so that they will absorb water readily and an abundance of moisture is received. With abundant rainfall during the remainder of the season this region can produce large quantities of corn and of the sorghums this year, and if the land not used for these crops is properly prepared it will be in excellent condition for the seeding of wheat next fall. In some sections of the West soils were eroded by wind more than twenty years ago; in other areas erosion took place fifteen years ago. These soils were not ruined, but have produced excellent yields of grain and forage crops every year since that time when climatic conditions have been favorable. As nearly as can be determined by observation they are as productive as are adjacent soils that were not eroded by wind.

A program of erosion prevention

Although most of the soils of western portions of the Great Plains have not been seriously injured by wind erosion, it is important that everything possible be done to prevent such injury. If proper methods of cultivation and of soil management are practiced, much can be done to prevent a repetition of the condition that exists this year. During the present emergency the most practical thing to do is to list or otherwise cultivate the soil to sufficient depth to bring the hard cloddy material to the surface. A rough cloddy surface will not blow.

A long-time program for the control of soil blowing will vary with soil and climatic conditions. It will perhaps be advisable to take some of the more sandy soils (which do not cover an extensive area) out of cultivation and establish some type of cover on them. Similar measures may also be advisable on some of the heavier soils that occupy exposed areas and are quite subject to erosion. But over most of the region soil erosion can be prevented by practicing strip farming in which strips of wheat, feed crops and fallow or wheat and fallow will alternate on the field. These strips will be at right angles with the direction of the prevail-

ing winds, or, on sloping lands, they will follow the contour. The wheat-stubble land to be used for feed crops or fallow will retain the stubble during the winter and until the danger of soil blowing is over the following spring. During years of good summer and fall precipitation this land may be listed in the late fall or early winter and left in a rough condition until late spring. When the fallow follows a feed crop, the land will be listed in the late fall if there is not sufficient stubble to prevent wind erosion.

Timely cultivation with the correct types of implements will aid materially in preventing wind erosion of soils. A greater use of the lister and of the spring-tooth and duck-foot types of implements when the soil contains sufficient moisture will tend to leave a rough cloddy surface that will not blow. Cultivating when the soil is too dry should not be practiced, especially with the disk. Disk implements have a place in this region, but they must be used judiciously or the soil will be made more susceptible to blowing.

Another important factor in a long-time program for this region is the carrying over of feed supplies from years of high production to be used during periods of drought. This practice would aid in providing a more uniform feed supply for livestock and would eliminate the necessity of harvesting all plant growth during the years of low production.

With the development of such a program on the farms of the region, the agriculture will become more stable, and over a period of years will be more profitable. Such a program will also materially improve living conditions in the future.

Distribution of Horizontal Shear Analyzed for Special Sections

By Glen N. Cox

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A NUMBER of textbooks on strength of materials and also several engineers' handbooks contain the statement that the horizontal unit shearing stress for any section of a beam is a maximum at the neutral axis. This may or may not be the case, depending upon the shape of the cross-section of the beam.

For illustration, a parabolic and a triangular cross-section of beam have been studied. The unit stress is given by the formula

$$S = \frac{V}{It} a' \bar{y}$$

where V is the vertical shear at the section, I the centroidal moment of inertia of the cross-sectional area of the beam, t is the width of the beam at the point where the shearing unit stress is desired, a' is the area of the beam on either side of the point where t is measured, $\bar{y}$ is the distance from the centroidal axis of the beam to the centroid of the area a'.

This formula is based upon the usual flexure formula $S = Mc/I$, and, like it, applies only when the unit stresses are below the proportional limit of the material. For the parabolic cross-section,

$$a' = \frac{2}{3}(0.6b - x)\,t$$

$$\bar{y} = 0.6\,(0.4b + x)$$

$$S = \frac{4V}{10\,t}(0.6b - x)\,(0.4b + x)$$

$$\text{Let } \frac{4V}{10\,t} = K$$

When the first derivative of the above expression is set equal to zero, it is found that the shearing unit stress is a maximum when x equals $0.1b$. This is at the center of the area.

For the triangular cross-section,

$$a' = \frac{t}{2}\left(\frac{2}{3}h - x\right)$$

$$\bar{y} = \frac{2}{3}\left(\frac{h}{3} + x\right)$$

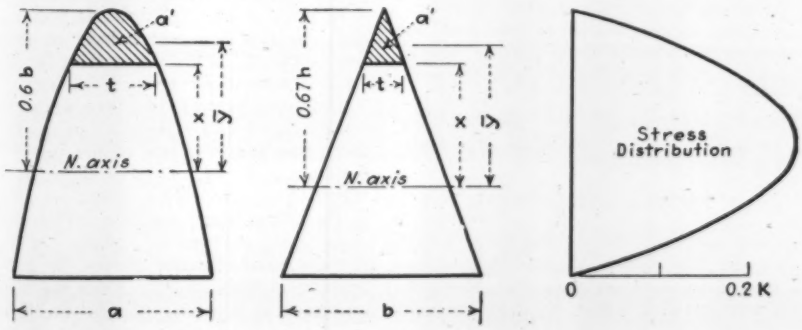
$$S = \frac{V}{3t}\left(\frac{2}{3}h - x\right)\left(\frac{h}{3} + x\right)$$

$$\text{Let } \frac{V}{3\,t} = K$$

When the first derivative is set equal to zero, it is found that the maximum sheering stress occurs when x equals $h/6$. This also represents the center of the area.

When the cross-section of the beam is rectangular, or when the width at the neutral axis is as small as at any other point along the beam, the shearing unit stress is a maximum at the neutral axis regardless of the position of that axis.

DISTRIBUTION OF SHEARING STRESS for parabolic and triangular cross-sections.



Rubber Pavement in Tunnel Found a Source of Trouble

WHEN the vehicle tunnel under the Mersey River between Liverpool and Birkenhead, England, was built (*ENR*, Nov. 16, 1933, p. 581), about 2,000 sq.yd. of rubber pavement was installed at a point where the vehicle tunnel passes over a railway tunnel. The use of a resilient pavement was one of the requirements written into the agreement between the commission that built the tunnel and the railway company at the time the work was undertaken. A cast-iron block 2 in. thick with a checkered surface is used for paving the remainder of the tunnel. The rubber paving also is 2 in. thick. The grade on the section paved with rubber is 3.3 per cent.

Recently Ole Singstad, chief consulting engineer on tunnels to the Port of New York Authority and former chief engineer of the Holland Tunnel at New York, made a study of traffic and operating conditions in vehicle tunnels in Europe. In commenting on these tunnels at a meeting of the Metropolitan Section, American Society of Civil Engineers, Mr. Singstad stated that the rubber paving in the Mersey Tunnel had not turned out to be advantageous from an operating viewpoint. The pavement has been found to be much more slippery than the cast-iron pavement used in the remainder of the tunnel; skidding on the pavement is a frequent cause of trouble, and as a result the rubber paving is kept sanded with sharp grit to reduce the risk of skidding.

AN ENGINEER'S RECOLLECTIONS

By JOHN F. STEVENS
Consulting Engineer, Baltimore, Md.

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The Discovery of Marias Pass

Legend tells of a low gap through the Rocky Mountains at the headwaters of the Marias River—Hard traveling into the mountains—Discovery of the pass made late in the day—Walking all night to keep from freezing

THE SEARCH FOR A PASS through the Rocky Mountains at the headwaters of the Marias River took definite form in 1853 when Major Isaac I. Stevens undertook to make explorations and surveys to ascertain the most practical route for a railroad to the Pacific Ocean. Major Stevens failed to find a pass in that region and crossed the mountains farther south. Occasionally during the next 35 years others tried to locate the legendary pass, but without success. It remained for John F. Stevens, in the early winter of 1889, to discover the pass. Of the many single events in his varied career it stands out as the most spectacular. His own account is given in the following, the fifth of a series of reminiscences. —EDITOR.

THE PICTURE of railway development in the Northwest of the United States as it is now sketched was far from complete in the year 1889. The Great Northern Ry. had pushed its main line from Minnesota to a point 4 miles west of the small settlement of Havre, in the central part of the northern section of Montana. From there it had built a line southwest through Great Falls and Helena to Butte. During that year its controlling genius, Jas. J. Hill, took the first open steps looking to the extension of the main line to the waters of the Pacific Ocean.

E. H. Beckler was appointed chief engineer of the projected extension. I knew him only slightly. Mr. Hill I had seen occasionally, but did not know him; and at that time I doubt if he knew of my existence, although he may have, as I had gained some little reputation by my four years' work on the Canadian Pacific Ry., of which he had been managing director.

In November Mr. Beckler called me to a conference at Helena, on which occasion he briefly outlined the existing situation, saying that the contract had been let for the construction of the line as far west as Spokane, but that no decision had been reached as to what route would be taken west of Havre, as neither he or anyone else knew where the road would cross the Rocky Mountains. He asked me if I would undertake to ascertain if such a thing as Marias Pass existed, and if so, if it was feasible for a railway to adopt it as a route through the mountains.

FIG. 1—JOHN F. STEVENS, standing at the base of the statue in Marias Pass that represents him as he appeared on Dec. 11, 1889, when he discovered that route through the mountains.

I said that I would, and went at once to Fort Assinniboine, a military post 7 miles west of Havre, where I met with the fullest cooperation from the commandant. He furnished me with a mule team, a covered wagon, a soldier driver and a saddle horse, and after taking on a few supplies we pulled out for the Blackfoot Agency, which was estimated to be about 180 miles distant.

It was cold when we left the post, but nothing to what it became later. Almost immediately a series of light blizzards came up, and they continued almost uninterruptedly until we reached the agency, but we managed the trip without much suffering.

Earlier search for a pass

To digress: The only railway which crossed the Rocky Mountains in Montana at that time was the Northern Pacific, which found its way through Mullans Pass with a track elevation in the tunnel of 5,563 ft. above sea level. There were known to be two feasible passes north of Mullans Pass, but both of them were south of the latitude of Great Falls and more than 150 miles south of the latitude of Havre.

It had been decided that the extension of the Great Northern must follow the valley of the Kootenai River in western Montana and northern Idaho, after crossing the Rocky and Cabinet ranges. But to reach that valley, it would have been necessary first to cross the Kalispell Valley, which lies between those two ranges directly west from Havre. Therefore, to use either of the two southern passes, the line would have been forced to leave the Havre-Butte line at some point southwest of Great Falls, and after crossing the Rockies turn sharply to the northwest and find a practicable route to the Kalispell Valley.

The adoption of such a route would have placed the railway under a heavy and permanent handicap in the handling of through traffic in competition with the other transcontinental lines. It would have given it a line with much more severe gradients and alignment than it now has; one that would have been more than 100 miles longer, altogether putting it out of the picture as far as movement of through traffic was concerned. The problem of finding a much better route was a vital one, and the crux of the problem was this: Did a feasible pass exist, one nearer to a direct line west from Havre, and could is be found quickly? Time was pressing, and Mr. Hill was not a man to delay the execution of his plans once he had decided upon their general features.

For many years it had been known to the Blackfeet and Kalispell Indians that there was a gap at one of the heads of the Marias River. These Indians probably had traveled it for countless years in their hereditary warfare. The river rises in a number of places in the Rockies, and flowing thence in many branches which unite to form the main stream that discharges into the Mis-

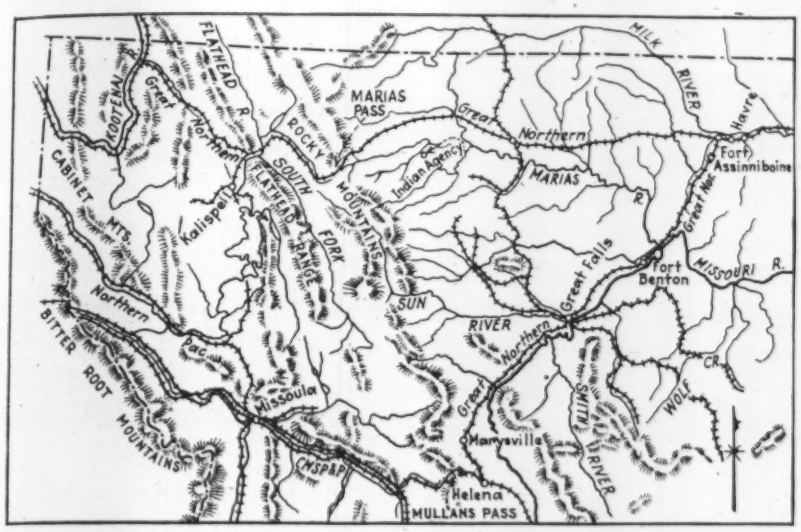


FIG. 2—MR. STEVENS began his overland travel in search of Marias Pass at Fort Assinniboine, and in going west followed closely the line subsequently followed by the Great Northern Railway.

souri a few miles north of Great Falls. Meriwether Lewis became obsessed with the belief that there must be a low gap in the mountains at the head of this river, and on his way back from the mouth of the Columbia River in 1806, he personally headed a small party in an attempt to find such a gap but failed to reach the mountains, owing to an encounter that he had with the Indians.

About 46 years later Colonel Isaac Stevens was sent by the government to make a reconnaissance for a railroad along a northern route, from the upper Mississippi Valley to the Pacific Ocean. Reaching the vicinity of what is now Havre, he turned southwest and then west, examining both the southern passes mentioned. After crossing them he made his way to what is now known as Flathead Lake.

He was not satisfied with the passes that he had explored, and later sent a small party eastward with orders to find a practicable one, which he still believed existed. This party went up the Middle Fork of the Flathead River and turned into one of its branches that heads in a high rugged gap leading to a fork of the Two Medicine River, a branch of the Marias, totally impracticable from a railway point of view. There the search ended. And so the matter rested for 36 years more, whan it fell to my lot to undertake the task.

The quest started

To resume: at the Indian Agency I tried to get some information about the legendary pass, but could get none. No white man would admit that there was such a one, and it is very doubtful if any of them knew about it. The Indians evidently knew, but not one of them would stir out of his log house in the winter weather. They also cherished a tribal superstition that a visit to that part of the mountains meant death to a visitor, by reason of a 'bad spirit' there, which was anathema to an Indian. Finally I found a Kalispell Indian who, I was told, had killed one of his tribe, and, fleeing through one of the southern passes, had been given sanctuary by the Blackfeet. By promising him good wages I got him to go along with me on my quest.

Buying some old snowshoe frames from the Indians, I patched up something that resembled snowshoes, which I knew would be needed. We were able to use the mule team nearly to the foot of the mountains, stopping at night in abandoned Indian cabins. When the deepening snow prevented further progress with the team, I sent it back to the last cabin with orders to remain there until my return, and we pushed on afoot with some food and our blankets. The Indian had never been far west of the agency, for he knew nothing whatever of that part of the country, and was not a guide in any sense of the word. I only wanted him to act as a messenger in case I met with disaster.

After reaching a point where some small valleys debouched from the mountains and finding nothing that looked favorable in two of them, I followed up another that looked like a fair prospect, and soon reached what was later called the False Summit, a few miles east of the real pass. For a short while I thought that I was on the main divide, but something, possible a sixth sense, urged me to keep going and I went ahead. Very soon the Indian signified by signs that he had gotten enough, and would go no farther. Finding some dead dry wood I built a small fire, left him there and went on alone. To my surprise after a few miles I walked directly into the Pass, and was on the Continental Divide.

Through the pass

Although believing that the gap in which I stood and through which I was looking led to Pacific waters, I knew that it would be an inexcusable blunder if I was deceived, so I went on through it and down into the western valley until I felt absolutely certain that I had crossed the main divide, and that the waters of the stream under the snow beneath my feet eventually reached the Pacific Ocean.

The night was rapidly approaching,

FIG. 3—THE ROUTE from the Blackfeet Indian Agency to the pass, as closely as Mr. Stevens can recall, was up the valley of Two Medicine Creek. But Mr. Stevens followed the South Fork, whereas earlier explorers had followed the main stream and had crossed the mountains through Two Medicine Pass at a much higher altitude.

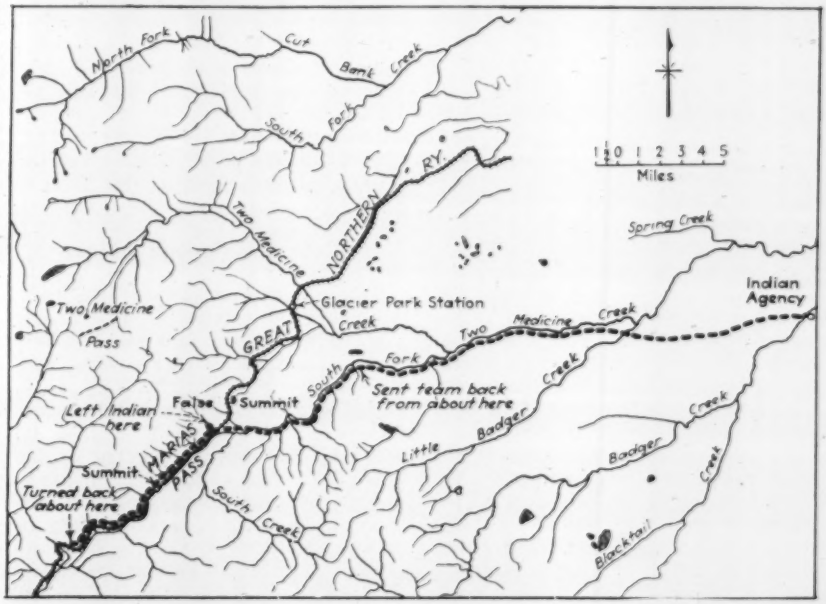


FIG. 4—MARIAS PASS, looking west toward the Pacific, a picture taken at the unveiling of the Stevens statue, July 21, 1925.

and I retraced my steps, hoping to reach the Indian and more especially the fire before complete darkness overtook me, but when I reached the summit after a seemingly hopeless struggle it was well after all traces of daylight had vanished. Aside from being very tired, it would have been dangerous to try to find my way in darkness down along the icy slopes and deep snow of the small canyon which I had followed on my way up. This day was Dec. 11, 1889. I shall not forget that day and its night, as long as memory lingers.

Walking to keep warm

There was no possibility of making a fire with nothing but green brush and evergreens showing above the deep snow. So I tramped a path through it until it would bear me without snowshoes, and walked it back and forth until the first streak of daylight. I had some bread and bacon, both frozen, and did not suffer from hunger. Had I not kept moving I would have frozen to death. It was a long night. When I got back to the agency, I found that the thermometer had registered 36 deg. below on that night, 1,600 ft. lower in elevation than the pass. It must have been 40 deg. or lower up there.

I found the Indian where I had left him. He had let the fire go out and was nearly frozen. I beat some life back into him, and we got back to the agency. He was an unusually worthless specimen and was killed some years later in a drunken brawl.

I had taken several aneroid readings on the summit, and while such readings are not strictly reliable, I knew that I stood in the lowest pass through the Rocky Mountains in the United States, north of where the Southern Pacific crosses the Continental Divide, near Lordsburg, N. M. The Great Northern Ry. goes through Marias Pass without a tunnel, but on a light embankment, at an elevation of 5,213 ft. above sea level. And beside the track near the spot where I spent that memorable night stands a heroic bronze statue depicting me as I appeared there 36 years before. It was erected by the Great Northern Ry. and dedicated on July 21st, 1925, a very deeply appreciated recognition.

Sending the team back to Fort Assinniboine, I made my way to Helena and verbally reported my findings to the chief engineer. While I realized later that the exploration made under the conditions that existed was unusual and hazardous, I regarded it at the time as only another engineering experience.

Acting at once upon my report, decision was quickly made to build the extension through Marias Pass, which lies directly west of Havre. Locating parties were placed in the field, the line located through the west of the pass, and construction was pressed as vigorously as the weather permitted. My assignment in the service took me elsewhere amid other scenes and problems for which no solution had been found at that time.

* * *

Not the first through the pass

I have never, verbally or otherwise, in public or in private, asserted that I was the first white man to cross the Rocky Mountains by Marias Pass, and I am not now making such a claim, for I regard it as open to considerable doubt. Meriwether Lewis' effort in 1806 to find a feasible pass at some one of the heads of the Marias River, and his failure to do so, are matters of authentic history. His own remarkable diary is unimpeachable testimony. The same applies to the efforts of Colonel Stevens in 1853, although Little Dog, a Piegan Blackfoot Indian, told him that there was a low gap in that region. As a matter of established fact, the only members of either expedition who crossed the Rockies anywhere in or near that latitude were Colonel Stevens' men, who crossed at the head of Two Medicine River, several miles north of the true pass. It is more certain than legendary lore that the Blackfeet and Kalispell Indians had used a trail through Marias Pass for generations, perhaps centuries, in their tribal wars. But during the 47 years that intervened between Lewis' and Colonel Stevens' unsuccessful attempts many white trappers and hunters, sent out by the fur companies, were in search of beaver and other fur-bearing animals on the plains, in the foothills and probably in the mountains. It is likely that some of these men crossed the range, and if they did, they might have used this trail and so may have white hunters years later. Without authentic records, I believe that they probably did cross there.

At my conference in Helena with Mr. Beckler, chief engineer of the Great Northern, he said that he thought it was a well-established fact that there was a pass at the head of the Marias River, but that no one seemed to know where it was. Mr. Barclay, a Canadian engineer, had been sent by Mr. Hill a year previously to try and find it, but he had failed to do so. Major Rogers, another engineer, had spent some time west of the mountains, but had developed nothing of value in regard to the Main Range. Mr. Beckler himself was going to send engineer Haskell in from the West, to see what he could find. At this time locating parties of engineers were at work on a line, or lines through, and west of the two southern passes that I have noted. It was evident that the chief engineer believed that there was a pass better than either of the two in which

his parties were working, but he could not risk losing valuable time in the event that the better pass proved a myth. When Mr. Beckler's report of what I had found reached Mr. Hill, he at once ordered all surveys via the southern passes abandoned and the engineering parties transferred to Marias Pass and west of there, which was done and the problem was solved.

Mr. Haskell's attempt at exploration resulted in nothing of value in the solution of the problem. He left Kalispell with one man late in the winter of '89-90, long after I had been in the pass. They made their way up the Flathead River and followed up the South Fork or turned up a branch coming in from the southeast, about 14 miles west of Marias Pass, reaching no summit whatever. They ran out of food and nearly starved and froze made their way back and reached one of the engineering parties that had been moved there from the southern passes. Mr. Haskell gave me this information in person, when he was reporting to me the next year, west of Spokane.

The official record

The point and credit for discovery rests here: The United States Geographic Board, established by Congress years ago, is the court of last resort in matters of naming natural features and incidents pertaining to lands that come under the jurisdiction of the United States. Its ruling, made long ago, is that the first one who explores and makes publicly known the results of his explorations is the one who is entitled to the name of discoverer, regardless of how many had previously visited that particular place. And under its ruling made in the case of the canyon leading west from the pass, I am the discoverer of Marias Pass.

The canyon, which leads westward from the pass to Belton, 45 miles, was called, colloquially "Theodore Roosevelt Canyon."

On Jan. 9, 1929, the board announced the following ruling: "John F. Stevens Canyon, Flathead County, traversed by the south boundary of Glacier National Park between Marias Pass and Belton, near latitude 48° 19′, longitude 113° 21′. For John F. Stevens, C. E., who on December 11, 1889, explored the low pass across the Continental Divide called Marias by Lewis in 1806. This pass, while well known to the Blackfeet and other Indian tribes, had never before been traversed by a white man until Stevens went alone to an through it until the Western flowing stream convinced him of his success."

Lewis named the river "Marias," from which, after its discovery, the pass took its name.

The above quotation is the ruling of the United States Geographic Board and is conclusive as to holder of title.

Whatever hardships and threatened dangers I may have confronted in my quest were compensated for many times over by the fact that the exploration made possible my connection with the Great Northern Ry. and with Mr. Hill, which I look back upon as the most satisfactory of my long and diversified career as an engineer.

Special Arc-Welded Connections in New Building at R.P.I.

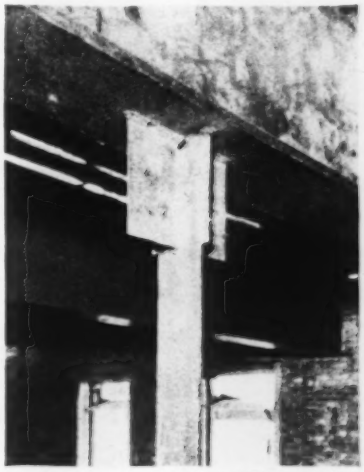
By LeRoy W. Clark
Superintendent of Buildings, Rensselaer Polytechnic Institute, Troy, N. Y.

THE ALL-WELDED FRAME of the new Palmer C. Ricketts Laboratory, approaching completion on the campus of the Rensselaer Polytechnic Institute, contains several unusual types of connections—in particular one for a series of hangers that support a part of the third floor. The building, four stories high and of wall-bearing type, will house the laboratories for aeronautical engineering, chemical engineering, industrial chemistry and metallurgical engineering.

Typical connections are shown in the accompanying illustration. Most of the beam connections are made with a T-bar. In order to avoid the use of a deep girder over the second-floor lecture room, it was decided to hang the third-floor steel from heavy girders in the fourth floor. This was accomplished by using 6x⅝-in. plate hangers, which were field-welded between two 7x4x⅜-in. angles, that had been shop-welded to the under side of the girder. The rafters were also hung from the roof beams, and at the eaves where it was necessary to cut away some of the rafter sections new flanges were welded on.

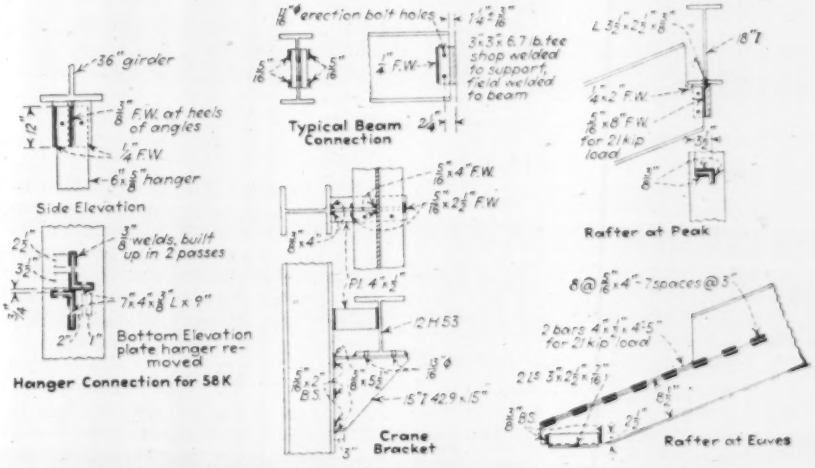
One of the great advantages of welded construction developed when it became necessary to lower part of the fourth-floor beams about 2 in. after the welding had been completed. These beams were simply burned loose and rewelded, with a minimum of trouble and expense.

The general contractor for the building is the William L. Crow Construction Co. Joseph M. Lawlor is the architect. The steelwork was designed by Howard M. Baird, with Gilbert D. Fish as consultant on welding.



General Electric Photo

WELDED CONNECTION of third-floor hangers to bottom flange of fourth-floor girders.



TYPICAL WELDED DETAILS used in the new Palmer C. Ricketts Laboratory Building at Rensselaer Polytechnic Institute.

Unique Design and Construction of Steel Ribbed Domes

Welded steel planetarium dome, 85 ft. in diameter, many times statically indeterminate for lateral forces, involves complex stress distribution—New method of analysis simplifies problem and results in economical design—Joints are welded electrically

By R. McC. Beanfield
Consulting Engineer, Los Angeles, Calif.

THE recently completed Griffith Observatory at Los Angeles is a structure in which astronomical requirements emphasized the need for rigidity and durability to an extent that called for unusual attention to details of design and construction. Features of the structure include two revolving domes 31 ft. in diameter and two fixed domes 85 and 40 ft. in diameter, respectively. The largest dome houses the planetarium, an instrument for projecting on an artificial celestial sphere the positions and movements of the solar and stellar systems, thus making it possible to show in a few moments simulations of changes and combinations whose actual occurrence in the sky would come about only in thousands of years. This article is devoted mainly to a discussion of methods of analysis used in designing the structural frames of the domes.

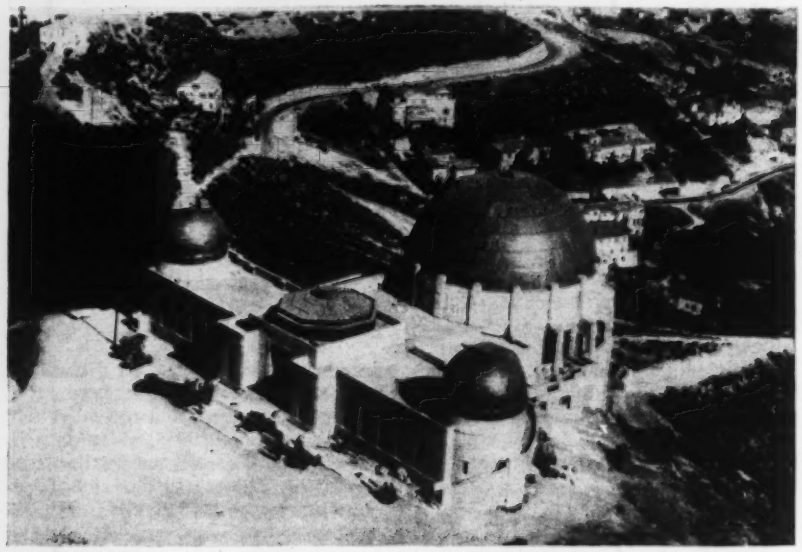


FIG. 1—GENERAL VIEW of Griffith Observatory nearing completion on a hill overlooking Los Angeles. Domes are framed with steel ribs.

The frame of the planetarium dome is a combination of structural steel and reinforced concrete, designed for a horizontal force or seismic resistance of 0.08 gravity and wind of 30 lb. per sq.ft. The building as a whole was constructed as rigidly as practical, to reduce its natural period of vibration, and care was taken to avoid a combination of structural units having different vibration periods. This was accomplished by tying isolated footings into a continuous and combined foundation plan; by judicious use of reinforced-concrete walls; by designing so that deformations in main structural units would be a minimum; by continuity of construction; and by the use of arc-welded connections, to resist large bending moments.

Fundamentally, the steel ribbed polygonal domes over the planetarium and over the main foyer are many times statically indeterminate for either gravity or wind loads. An analysis of stresses in these domes was made by a recently developed method that involves a new conception of stress distribution. For axially symmetrical vertical loads the matter of stress analysis becomes a problem of statics. For wind and seismic loads, however, the problem involves two-dimensional, statically indeterminate distribution of stresses. The methods of solution used for all loadings are outlined in the following.

For vertical or gravity loads, actual calculations by the elastic theory showed that if the rings are spaced close together, the lines of pressure for ribs in the vertical plane do not deviate materially from their geometric center lines. This condition permits the assumption that the dome is statically determinate. Accordingly, by assuming each rib to be a cantilever fixed at the abutments (concrete foundation) it is possible to calculate the stresses in ribs and rings by simple statics, a plan of analysis somewhat similar to the well-known Schwedler method.

Using a general formula developed by the author for analysis of rib and ring forces in a polygonal dome due to symmetrical vertical loads, the following plan is followed: By reason of axial symmetry it is sufficient to consider one rib only. By removing the rings a curved cantilever is obtained, fixed at joint 4 (Fig. 2a). To simplify explanation of the method of analysis, a dome of only four rings is used in which the bending moments of the cantilever are Mo_2, Mo_3, and Mo_4 (Fig. 2a).

The horizontal force H in joint 1 is found by taking moments about joint 2:

$$H_1 = \frac{Mo_2}{h_1}$$

$$\text{similarly } H_2 = \frac{Mo_3 - H_1(h_1 + h_2)}{h_2}$$

$$H_3 = \frac{Mo_4 - H_1(h_1 + h_2 + h_3) - H_2(h_2 + h_3)}{h_3}$$

As $\Sigma H = O$, $H_4 = -(H_1 + H_2 + H_3)$.

Having the horizontal thrusts H, the ring forces are obtained from $R = \frac{H}{2 \sin \frac{B}{2}}$, which is the component of the H thrust in the direction of the rings (Fig. 2b).

In the above analysis the axis of the rib and the line of pressure will coincide at the joints only. The ordinates to the line of pressure between the joints are given by the following expressions, derived by simple statics (Fig. 2c):

$Y_{12} = \frac{Mo}{H_1}$ between rings 1 and 2.

$Mo = \Sigma M$ to left of section.

$Y_{23} = \frac{Mo + H_2 h_1}{H_1 + H_2}$ between rings 2 and 3.

$Y_{34} = \frac{Mo + H_3 h_1 + H_3(h_1 + h_2)}{H_1 + H_2 + H_3}$ between rings 3 and 4.

The bending moments at any point in the rib, as for example between joint 2 and 3, are

$M = (H_1 + H_2)(y - y_{23})$ (Fig. 2c).

y = geometrical ordinate to actual rib.

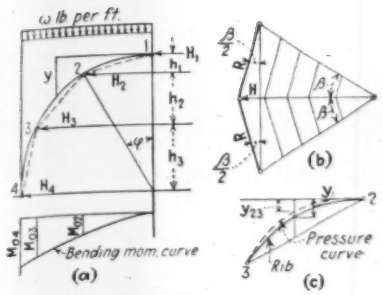


FIG. 2—DIAGRAMS illustrative of statical analysis in ribbed dome.

Having the vertical shear V of the cantilever rib, the axial forces, N, in the ribs are given by the formula:

$$N = V \sin \varphi + H \cos \varphi.$$

The polygonal ribbed-type dome with ring framing has an advantage over the spherical shell in that the ribbed dome can be supported directly by columns at each rib, whereas the spherical shell must have a continuous support around its base. By virtue of the symmetry of the gravity loads, there are practically no bending stresses in the ribs or rings. However, because of the unsymmetrical nature of the wind pressure, large bending stresses are introduced.

A method has been developed by F. Dischinger (Handbuch für Eisenbetonbau; Bearbeitet von H. J. Kraus: F. Dischinger; Berlin, 1928. Vol. 6, Part II) whereby wind stresses in shells of revolution may be analyzed by use of simple statics without intergrating the differential equations of the shells of revolution. This method is based on a sine law for anti-symmetrical wind loads—that is, stated wind pressure on the windward side and equal suction on the lee, or diametrically opposite, side (Fig. 3).

Dischinger's method can be applied to ribbed domes by assuming the finite panels formed by the ribs and rings to correspond with the infinitesimal elements considered in the analysis of the shell of revolution. The closer the spacing of the rings and ribs, the closer the approximation.

Dischinger's general formulas for anti-symmetrical wind loads adopted for ribbed framed polygonal domes are given below.

$W = W_o \sin \varphi \cos \psi$ = kip/ft.²
W_o = Wind press. on vert. wall

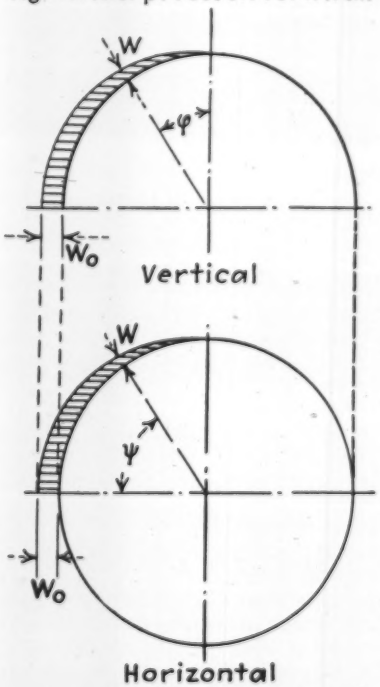


FIG. 3—WIND-PRESSURE DIAGRAM for computing wind stresses in dome.

Rib or meridian wind force $N_w = w_o R X A$

where w_o = maximum unit wind pressure, R = radius of the dome, X = coefficient (see table), and A = length of the ring between ribs.

Ring wind force $R_w = w_o R W$
where W = coefficient (see table).

Shear wind force $S_w = w_o R A_m Z$
where A_m = length of rib arc between rings, and Z = coefficient (see table).

The coefficients in the table were developed for forces at dome joints by Professor Dischinger and were taken by the writer from the reference given. Dischinger's work on this subject affords a most convenient and valuable aid to designers because of its general application.

Shearing forces cause bending moments at the joints of the ribs and rings (Fig. 5). The point of contraflexure is assumed to be at the middle of the ring between the ribs and at the middle of the rib between the rings. In reality the point of contraflexure will vary a negligible amount from the assumed position by reason of increased stiffness of the rings and because the coefficients are computed for the joints. By taking the average of the shearing force coefficients between adjacent joints and also the average lengths of adjacent rings, bending moments at the joints are obtained.

Rib moment, M_m = average $Z \times$ aver. length of adjacent rings.

Ring moment, $M_r = Z \times A_m \times \frac{A_r}{2}$

The bending moments at ring and rib joints are resisted by short angle knee-braces, designed for direct stress, and welded as indicated (Figs. 6 and 7). The lengths of the weld in each case were determined by the stress requirements. This provides a very stiff and economical joint. The ribs and rings were constructed of 10-in. H-beams of varying weights, to suit the stress conditions. Continuity in the ring joints at the ribs was obtained by electrically welding flange plates at top and bottom. The ribs were easily bent to the proper curvature of the dome; the rings were not curved but were constructed as chords between the ribs.

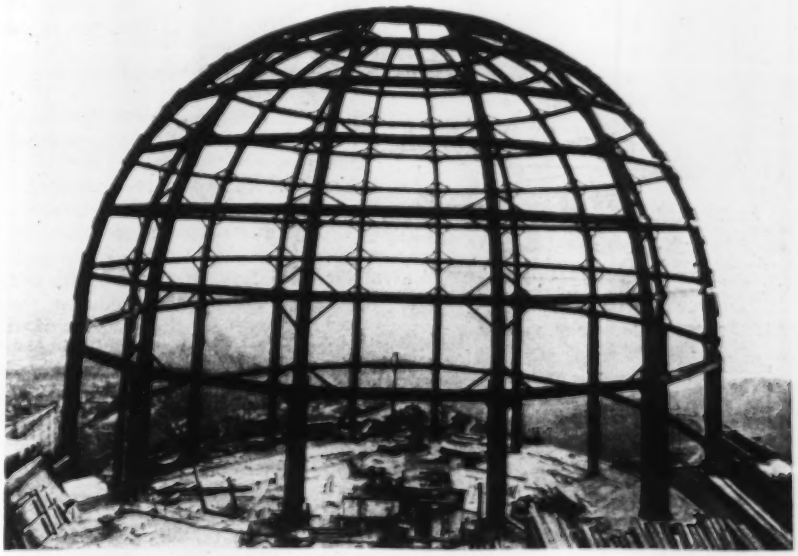


FIG. 4—PLANETARIUM STEEL FRAMING. The dome is 85 ft. in diameter. Note inclination of supporting columns and welded bracing to stiffen joints.

DISCHINGER'S COEFFICIENTS FOR FORCES IN DOME JOINTS

Angle φ	Rib X	Ring W	Shear Z
0	0.0000	0.0000	0.0000
10	.0143	.1334	.0419
15			.0656
20	.0840	.2580	.0894
25			.1132
30	.1187	.3913	.1371
35			.1635
40	.1455	.4793	.1900
45			.2205
50	.1615	.6045	.2510
55			.2860
60	.1605	.7055	.3210
65			.3667
70	.1409	.7958	.4125
75			.4662
80	.0909	.8943	.5200
85			.5933
90	0.0000	1.0000	.6667

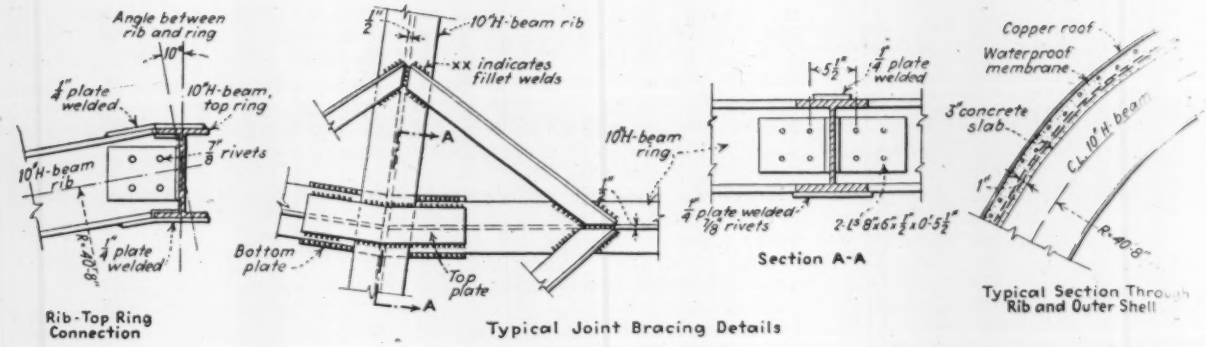


FIG. 7—TYPICAL CONNECTIONS in dome frame (a and b) and detail of concrete shell (c).

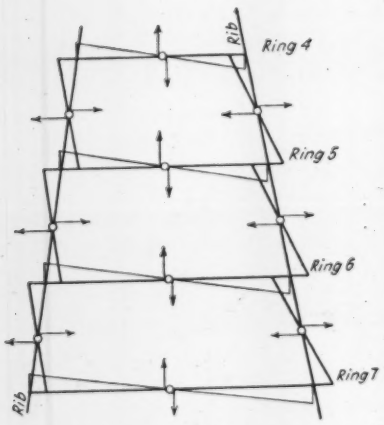


FIG. 5—WIND MOMENT distribution in rings and ribs of dome.

Rivet bolts were used throughout in place of rivets and were very satisfactory. Only punched holes were used, and no reaming or drilling was necessary. Erection of the steel dome framing was facilitated by use of a central timber tower, which supported the upper circular ring until the ribs were connected.

Columns supporting the main dome were inclined for architectural reasons.

FIG. 6—JOINT DETAIL showing welded angle brace to resist bending moments at junction of rings and ribs.

The inclined columns are braced by three polygonal rings, located in the walls below the dome at top, center and base of the columns. The two upper rings consist of steel H-beams; the base ring at the floor is reinforced concrete. Because of architectural restrictions, there is an eccentricity of 2 in. between the dome ribs and the supporting columns.

Assuming the rings to be hinged at the columns, a statically indeterminate system, in the second degree, was developed. Two elastic equations in terms of the displacements of the joints were required to obtain the unknown ring forces for each of the loading conditions: namely (1) vertical load from dome rib, (2) eccentricity between dome rib and column, (3) uniform vertical load on inclined column and (4) lateral loads on column. These equations are as follows:

$$X_1 \int M^2_1 ds + X_2 \int M_1 M_2 ds = \int M_o M_1 ds$$

$$X_1 \int M_1 M_2 ds + X_2 \int M^2_2 ds = \int M_o M_2 ds$$

where X_1 = unknown horizontal force in upper ring, X_2 = unknown horizontal force in middle ring, M_o = moment caused by actual loads in columns fixed at base only, M_1 = moment caused by unit force at upper rib, and M_2 = moment caused by unit force at middle rib.

Lateral loads on the dome structure, caused by wind and earthquake, are resisted in addition to the columns by the heavily reinforced concrete abutments and the framing systems in roofs and floors of contiguous parts of the structure.

The two revolving steel-ribbed domes with large openings for a 12-in. refracting telescope and a coelostat, respectively, were designed with three box-type steel ribs as semicircular arches with fixed ends. The horizontal base ring girder was designed to be stiff enough to safely assume complete restraint at the lower ends of the vertical ribs. The arch-rib analysis was greatly simplified by the use of the tabular coefficients found in "Trusses and Arches, Part III," by Charles E. Greene.

On account of the large shutter openings in the revolving domes, the principal ribs are subjected to torsional moments. The stress distribution was found by calculating the magnitude of the torque for varying conditions of loads on the ribs.

Most of the steel connections in the revolving domes were made by arc-welding. Considerable difficulty was encountered in the field erection because of distortion of the various dome units caused by residual welding stresses. A large amount of the distortion could have been eliminated by proper welding procedure and a more liberal use of tack bolts.

The structural, mechanical and electrical plans were prepared by the writer for the architects, John C. Austin and Frederic M. Ashley. The general contractor was the Simpson Construction Co. The Pacific Iron & Steel Co., of Los Angeles, fabricated and erected the structural steel.

Cuban-Public Works Program Making Progress

A public-works program inaugurated in Cuba on Jan. 1, 1934, has made appreciable progress, according to statistics just issued by the Cuban Department of Public Works. These show that $4,693,662 was appropriated for the prosecution of public works under its supervision. Of the 270 projects covered by the credits, 83 have been completed, 145 were in process of execution, and 42 were still under study on Feb. 28, 1935.

Construction of and repairs to highways, streets and bridges accounts for almost three-fifths of the credits, or in the period mentioned, $2,639,230, while for buildings, waterworks, schools and corresponding work $1,657,171 was allotted. The sum of $232,443 was assigned to construction and upkeep of lighthouses and aids to navigation, and $164,818 to port and wharf projects.

The largest single beneficiary of the program in charge of the Public Works Department is the university, for which appropriations totaling $609,394 have been voted. Next is the group of waterworks and aqueduct projects, for which $500,000 is available. City ornamentation projects are also taking substantial sums.

Modern Road Bridge Outlet for Norfolk, Va.

Old timber trestle and swing span replaced by steel and concrete viaduct with a two-leaf bascule carrying a 40-ft. roadway and two 6½-ft. sidewalks

By R. P. Ellison
District Engineer, State Dept. of Highways, Suffolk, Va.

ONE of the larger road bridges of the South Atlantic States, located at Norfolk, Va., is scheduled for completion this spring. This bridge is 1,521 ft. long across the eastern branch of the Elizabeth River. The construction of the bridge involved interesting features because of the type of foundations and the proximity of the new structure to an old bridge, the center swing span of which had to be free to operate frequently for navigation and a heavy road traffic. Some of the structural design is also deserving of mention.

Location and structure

Situated in the bight of land formed by the James River and its tributaries, Norfolk, Va., is separated by the two branches of the Elizabeth River from territory to the west and south. The situation is roughly indicated by the sketch map Fig. 2. Outlet to Portsmouth, except by ferry, was by bridges across the eastern branch of the Elizabeth and over a considerable detour south to a toll bridge (outside the map limits) crossing the southern branch. The same eastern branch bridges were the outlets to southern Virginia and eastern North Carolina and their agricultural and industrial sources of trade for Norfolk.

The old eastern branch bridge on Compostella Road, a narrow timber trestle with a steel swing span, was the bottleneck in this road route from and to the city. Increasing traffic has for some time called for better accommodation, and a new bridge was planned by the director of public works of Norfolk. N.I.R.A. funds were secured for its construction, under the supervision of the Virginia department of highways. Fig. 1 is an air view showing the relative locations of the old and new bridges; the new bridge is close alongside the old (at the ends, in fact, the roadways overlap), the new alignment departing from the old just enough to provide clearance. In profile, however, the roadway of the new bridge rises each way from street level on the two shores to an elevation about 15 ft. higher than that of the old bridge at the center of the bascule span.

FIG. 1—WIDE ROAD BRIDGE being constructed by the side of the old trestle carrying traffic to Compostella Road, running south from Norfolk, Va.

The new bridge consists of a bascule span section 237½ ft. long, with a north approach viaduct 616 ft. long and a south approach viaduct 668 ft. long. A sectional elevation, Fig. 3, of the middle part of the bridge shows the type of structure. The viaduct spans, except at the ends of the bridge and for the two spans with facia arches at each end of the bascule, are alternately 60 ft. and 66 ft. All viaduct spans are supported by four-column bents of concrete. The deck of the bridge is 63 ft. wide between railings and is divided into a 40-ft. roadway and two 6½-ft. sidewalks. Some of the details of most interest are as follows:

Viaduct construction

The girder spans are carried by four-column bents spaced alternately on 60-ft. and 66-ft. centers except at the bascule span (Fig. 3) and at the bridge ends.

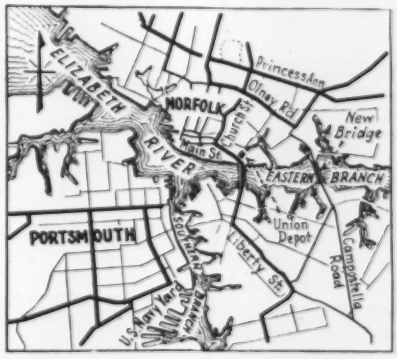


FIG. 2—ELIZABETH RIVER, showing location of new bridge giving road outlet south from Norfolk, Va.

The transverse section of Fig. 3 shows the bent construction, the pairs of bents at each end of the bascule being extra braced to each other and to the bascule piers, to give rigidity against bascule span loads; the others are unbraced except by the cap.

In constructing these bents an 8½-ft. steel open cylinder with a 5/16-in. shell was sunk through the water into the bottom for each column. These were dredged out by clamshell, as shown by Fig. 4, and then a cluster of nine wood piles was driven in the bottom of each cylinder using an ordinary steam piledriver and a follower. The bottom of the cylinder was then sealed with concrete deposited by tremie, the cylinder was pumped, and the pile tops were sawed off to elevation. The column footing and shaft were concreted within the cylinder to above high-water level. The cylinder shell was then removed except the bottom 5-ft. section. As will be noted, each column was protected at the water line by a steel jacket. The upper part of the bent was concreted in the usual manner.

In general, the cylinder sinking and piledriving encountered no difficulties beyond those of ensuring accurate location

and alignment. A barge was moored alongside the site of the bent, and a working platform on piles was built over the site, as indicated by Fig. 4. Excavating, pile-driving and concreting were performed by floating plant. Altogether the contractor had 84 cylinders to sink for 21 bents.

Eight rolled I-beams fabricated and erected in braced couples carry the roadway slab, the sidewalks being carried on brackets erected in the field. The girders are 33-in., 125-lb. beams, alternately 78 and 48 ft. long. The 78-ft. spans are placed on the bents 60 ft. apart, spanning the 60-ft. and giving a 9-ft. cantilever at each end. The 48-ft. spans are suspended between the opposite projecting cantilevers, forming with them 66-ft. spans between pairs of 60-ft. spans. It should be noted that because of the difficulty of rolling camber into the beams, all camber was taken up in the forms for the deck slab.

Bascule construction

As stated, the new bridge is located close to the east side of the old, with a clearance of about 4 ft. To maintain traffic over the old bridge and also through the navigable channel, it was necessary to place the bascule piers, which are 15 ft. higher than the floor of the old swing span, within narrowly defined limits. The channel at the north side of the old pivot pier was closed, all navigation being obliged to use the south channel; this was kept free of contractors' equipment or other obstructions at all times.

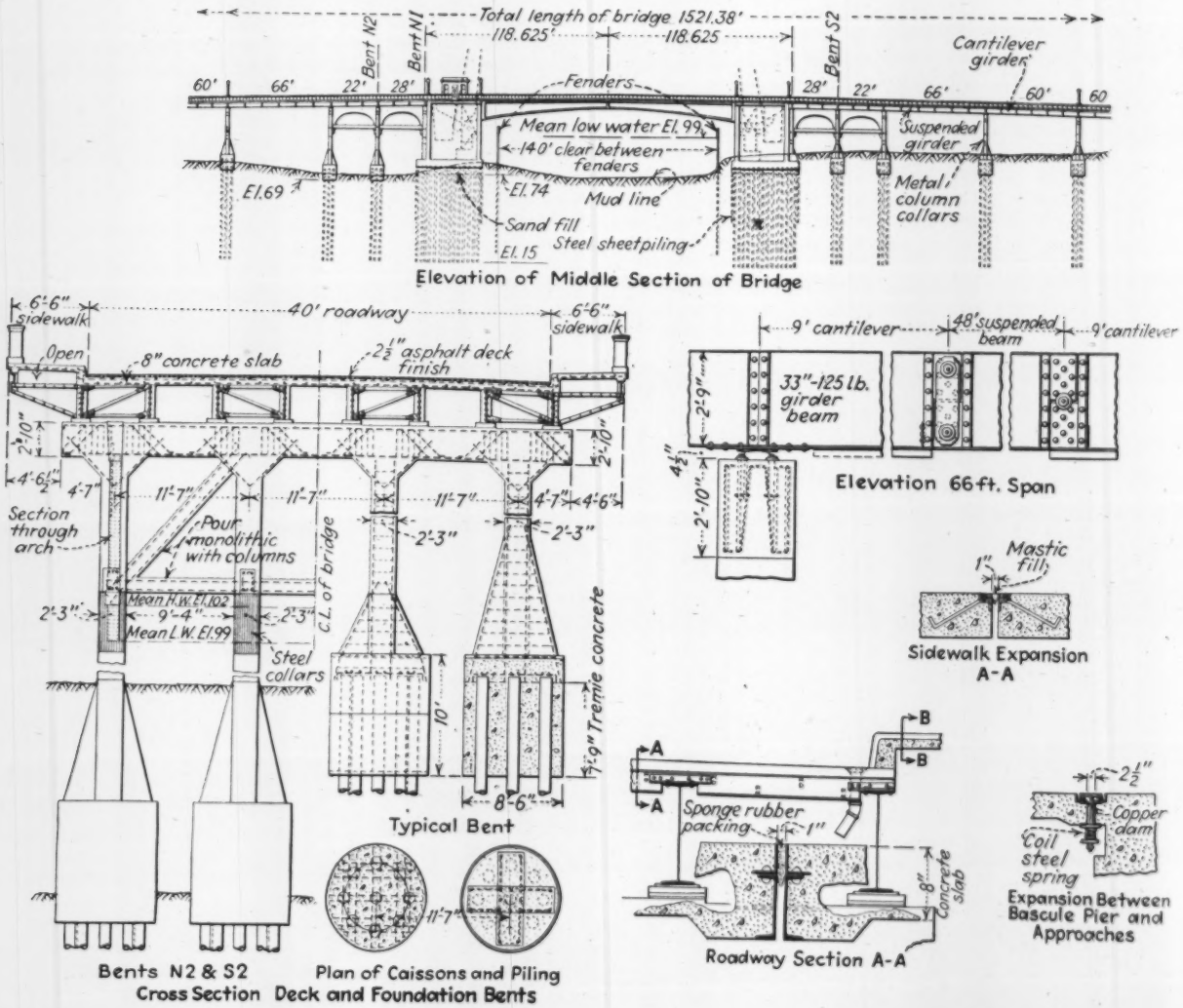
The south bascule pier was located as close as possible to the swinging arc of the old draw. The face of the north bascule pier, 162 ft. away, in its position a little to the north of the center of the old pivot pier, allowed full operation of the old bridge. The conditions made it necessary to swing the south end of the span between the new piers. The channel lies so as to permit full clearance by a swing of 7 deg. less than a right angle, and the few inches gained thereby were used to advantage in constructing these piers to meet the requirements.

The bascule span consists of a double-leaf, clear-deck, plate-girder unit of the rolling-lift type. It is 178 ft. long, c. to c. of bearings, and in the open position will provide for a 140-ft. clear opening over the navigable channel. When closed, it will have a clearance of more than 18 ft. above mean low water. It will be operated by electric power, with provisions for auxiliary hand-power operation; it will be erected, as the piers were, without obstructing the channel.

The bascule piers are of concrete, 67 ft. wide and 36 ft. measured along the roadway. They are of hollow construction and will contain sump pumps, counterweights and all necessary machinery for operating the bascule leaves. Each pier will have a small ornamental house, but otherwise the decks will be clear; one house will contain a switchboard and other operating devices, and the other will be a public convenience station.

These piers are carried on timber piles, 299 to the pier. Wash boring showed alternate layers of silt and silty sand underlying 28 ft. of soft mud. Piles

FIG. 3—FOUNDATION and deck details of Norfolk bridge in which a double-leaf bascule span is flanked by long viaducts founded on steel cylinders and piles.



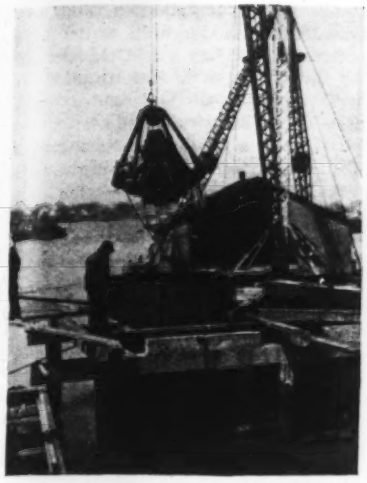


FIG. 4—EXCAVATING CYLINDER for a column and column footing for a four-column bent for the Norfolk bridge.

were driven with the aid of jets, to a bed of coarse sand at a depth of 78 ft. below the surface of the water and 57 ft. below cutoff.

A double row of spliced steel sheet-piling formed the cofferdams, and the lower part of the inner row was left in place around the pier footings. For the inner supports a frame 72x44 ft. and 22 ft. high, was built up of 12x14-in. timbers, thoroughly braced and launched from the ways of a shipyard at some distance from the job. The sheetpiling was first driven on one side and one end, and the frame was then floated up the river and into place. After they had served their purpose in constructing the south pier, the same timbers were again framed and launched for the north pier cofferdam.

Direction

The bridge was built under the supervision of the Virginia highway department, H. G. Shirley, commissioner. It was designed by the Norfolk department of public works, with J. E. Greiner as consultant.

The contractor on the job was the Tidewater Construction Corp., Norfolk, Va. The estimated cost of the bridge is $530,000.

Sewage-Sludge Fuel Value Related to Volatile Matter

Existing data analysed to determine the relationship between heat value and volatile matter content—Equations derived to aid in the determination of heat value in connection with disposal of sludge by incineration

By **Gordon M. Fair and Edward W. Moore**
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THERE IS today much interest in the incineration of sewage sludge as a method of disposal. Incineration is made economically practicable by withdrawing sufficient water from the sludge by preliminary treatment, such as vacuum filtration, to permit utilizing the fuel value of the sludge itself to drive off the remaining moisture while maintaining combustion. Fundamental to incineration, therefore, is a knowledge of the fuel value of the sludge.

The determination of fuel values requires the use of relatively expensive apparatus, which often is not available in sewage-works laboratories and the technique of which is often not familiar to plant operators. The determination of the volatile-matter content of sewage sludges[1], on the other hand, which has long been known to be related to the fuel value, is simple, and the apparatus employed is quite generally available in well-equipped sewage-works laboratories. There is, furthermore, a wealth of data on the volatile-matter content of sewage sludges for which the fuel values are unknown. It would be convenient, therefore, if the fuel value of a sludge could be predicted from a knowledge of its volatile-matter content. Preliminary calculations involving the fuel value of sludge could then be based on such predictions. It will appear that this can be done with a fair degree of accuracy, although the technique of volatile-matter determination still leaves much to be desired. It is the purpose of this paper to set forth certain relationships between fuel value and volatile-matter content of sewage sludges that may be found useful.

The authors have for some time been concerned with the evaluation of this relationship, and a preliminary article[2] on the subject has already been published. The accumulation of new data and the possibility of applying statistical methods to the analysis of the data now at hand have led them to review the subject in order to increase its usefulness in American practice. To this end, the data of German workers, previously included in their studies, have been omitted. The equations that will be suggested are based on correlation studies[3], which have been found useful in the statistical analysis of many types of physical data. The correlation method yields, in the value of r the coefficient of correlation, a measure of the agreement between the derived equation and the actual data. For perfect agreement, r equals unity, and its value becomes progressively smaller as the agreement becomes less perfect. Since the significance of r is not readily appreciated, the percentage difference between observed and calculated fuel value with respect to the calculated value has also been computed for each sludge, and a table of these differences is presented. Sludges resulting from activated-sludge treatment and from plain sedimentation are treated separately.

Plain-sedimentation solids

The data on plain-sedimentation solids, both digested and fresh, are presented in Fig. 1, which also shows the sources of the data. The following equation fits the data well:

$$Q = 85\,P^{1.085} - 700 \qquad (1)$$

where Q = fuel value in B.t.u. per lb. of dry solids, and P = per cent volatile matter in dry solids. The equation is represented on the diagram by a continuous curve. For this equation, the correlation coefficient is $r = 0.953 \pm .007$. The percentages of error in fuel values calculated from this equation are listed in Table 1. It will be seen from this

TABLE I—PLAIN-SEDIMENTATION SOLIDS

Range of Error, Per Cent	No. of Observations	Per Cent Error	Per Cent of Total Values with Less than Stated Error
0– 5.0	29	5	37.6
5.0–10.0	27	10	72.8
10.0–15.0	8	15	83.2
15.0–20.0	8	20	93.5
20.0–25.0	2	25	96.1
Over 25.0	3	28.5	100.0
Total ...	77		

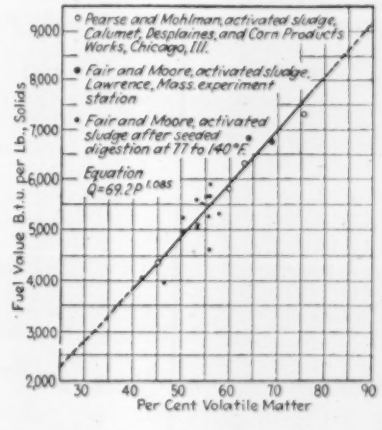

FIG. 1—FUEL VALUE of plain-sedimentation sludge, as disclosed by seven series of tests.

table that for three out of four of the sludges studied the difference between observed and calculated values is less than 10 per cent, and for four out of five it is less than 15 per cent. For the rest, 13 out of 77 values show deviations ranging from 15 to 28.5 per cent. It is believed that most of the larger variations recorded can be ascribed to imperfections in samplying, to variations in technique of volatile-matter determination between different laboratories, and to the presence of inert materials, such as grit, in the sludges.

The fresh sludges studied have, in general, volatile-matter contents of 60 to 85 per cent, and fuel values from 6,500 to 10,500 B.t.u. per lb. of dry solids. A fresh sludge consisting entirely of volatile matter would, from the projected curve, have a fuel value of about 12,000 B.t.u. per lb., and this figure may be taken as the average value of the volatile matter in fresh sludge. It is about the same as that for bituminous coal.

Digested sludges seldom appear to have fuel values greater than 6,500 B.t.u. and may fall as low as 2,000 B.t.u. when heavily digested. The volatile-matter contents run from 55 down to 25 per cent, but the majority of sludges are not digested to less than 35 per cent volatile mater. The more thoroughly digested sludges, by their trend, indicate clearly that the fuel value will become zero while the volatile-matter content is still appreciable. Extension of the lower portion of the chosen line shows this to occur at about 7 per cent volatile matter. However, in view of the small number of heavily digested sludges included in the study, extrapolation is not too dependable. The volatile-matter percentage at which the fuel value becomes zero is significant as a measure of the proportion of inorganic, or non-combustible, volatile matter found in sludge. This includes decomposable and volatile salts, such as the carbonates of ammonia, other carbonates, and possibly to a smaller extent the alkali chlorides. The relative quantities of these substances in sludge increase as digestion proceeds, so that the value obtained by extrapolation is a limiting value.

Activated sludges

The data for activated sludges, both digested and undigested, are shown in Fig. 2. Fewer values are available, and only a limited range of fuel value and volatile-matter content is covered. For this range the equation best fitting the data is

$$Q = 69.2\ P^{1.085} \qquad (2)$$

The symbols have the same significance as in Eq. (1). The correlation coefficient is $0.914 \pm .025$. The fact that it is less than the coefficient for sedimentation solids reflects the smaller number of values on which the study is based.

TABLE 2—ACTIVATED SOLIDS

Range of Error, Per Cent	No. of Observations	Per Cent Error	Per Cent of Total Values with Less than Stated Error
0– 5.0	13	5	65.0
5–10	5	10	90.0
10–15	1	15	95.0
15–20	1	15.9	100.0
Total....	20		

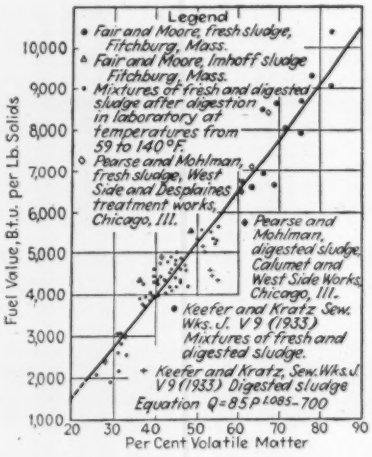

FIG. 2—FUEL VALUE of activated sludge, as disclosed by three series of tests.

The fit obtained is good, as is shown clearly by Table 2, which lists the percentages of error in the fuel values as calculated from the volatile-matter contents by Eq. (2). For activated sludges the difference between observed and calculated values is less than 5 per cent for two sludges in three and less than 10 per cent for nine out of ten. Activated sludge is more uniform in character and more finely divided than plain-sedimentation sludge, and can therefore be expected to give more uniform analytical results.

Undigested activated sludge, judging from the few values available, has a volatile-matter content of 60 to 75 per cent, and fuel values from 6,000 to 7,500 B.t.u. per lb. One exception is the activated sludge obtained by Pearse and Mohlman from raw sewage at the Calumet works, which has 45.3 per cent volatile matter and a fuel value of 4,390 B.t.u. After laboratory digestion, with seeding, the activated sludges used by the authors contain from 40 to 60 per cent volatile matter and from 4,000 to 6,000 B.t.u. per lb. The form of the equation for activated sludge is such that the volatile matter becomes zero when the fuel value is zero. This probably is not strictly true, but there are no data in the lower ranges of volatile-matter content from which an equation of the type (1) could be derived. Probably the same situation exists as in the case of plain-sedimentation solids—i.e., there is some volatile matter present which is inorganic and without fuel value. An activated sludge composed entirely of volatile matter would have a fuel value of 10,250 B.t.u. This would indicate that the organic matter of activated sludge has about 15 per cent less fuel value than that of plain-sedimentation solids. During activation, there is probably some destruction of values, with a resultant lowering of the substances possessing the highest fuel values, with a resultant lowering of the average fuel value of the organic compounds present. The fact that less gas per unit of volatile matter digested is obtained by digestion of activated sludge also indicates such destruction of substances of high thermal content in the process of activation.

Sludges containing chemicals

When chemicals are employed to aid sedimentation or filtration of sewage solids, a correction must be made for their presence in the sludge before the fuel value is estimated. Since the volatile-matter content is raised to a power greater than unity in the equations, the fuel value of sludges containing added chemicals, as calculated without correction, will be somewhat too low. It should be noted, however, that the correction must be based on the weight of chemical remaining in the sludge as precipitated, not on the weight actually added, since all of the chemical does not necessarily the application of such corrections appear in the final sludge. This makes somewhat difficult. The formulas for the corrected fuel values are, for plain-sedimentation and activated solids, respectively:

$$Q_c = \frac{85\left[P_c\left(1+\frac{P}{100}\right)\right]^{1.085} - 700}{1+\frac{P}{100}}, \text{ and} \qquad (1a)$$

$$Q_c = \frac{69.2\left[P_c\left(1+\frac{P}{100}\right)\right]^{1.085}}{1+\frac{P}{100}}, \qquad (2a)$$

where Q_c = fuel value, in B.t.u. per lb., of chemically treated sludge, P_c = per cent volatile matter in chemically treated sludge, and P = per cent of chemical, based on dry solids, remaining in the precipitated sludge.

Fortunately, the corrections are small with any reasonable dosage of chemicals. For example, let it be assumed that 5 per cent of ferric chloride, on the basis of dry solids, is added to a plain-sedimentation sludge containing originally 50 per cent volatile matter. Let it be further assumed that all the ferric chloride enters the sludge, an assumption not in accordance with fact but representing the worst condition with respect to magnitude of the correction. Then $P_c = 47.6$ per cent, and Q_c as calculated from (1a) becomes 4,790 B.t.u. per lb. of the chemically treated solids. From

(1), using 47.6 per cent directly, we obtain 4,930 B.t.u. per lb. The difference is less than 1 per cent.

It is hoped that the relationships here set forth may be of use to engineers in cases where an approximate estimate of the fuel value of sludges is desirable and where actual determinations of fuel value are not available or are inconvenient. The submission of any additional data that may exist will help the authors to establish these relationships on a firmer basis. The authors also believe that any improvement in the standardization of the technique of volatile-matter determination in different laboratories, especially with regard to temperature control, will materially increase the reliability and usefulness of predictions of the fuel value of sludges from their volatile-matter content.

REFERENCES

[1]"Standard Methods for Examination of Water and Sewage," A.P.H.A., 7th Ed. (1933), p. 96.

[2]Fair and Moore, *Sewage Works Journal*, IV, 242, 1932.

[3]Rietz, "Handbook of Mathematical Statistics," Cp. VIII.

Letters to the Editor

Reform in Home Financing

Sir—Your recent commentary on the national housing situation (*ENR*, March 28, 1935, p. 463) struck the keynote of a home financing plan which I have completed after several years of study and research. A more equitable homebuyer-seller-lender relationship than we have at present is urgently needed, and it is on this premise that I have built up my plan of home ownership, hereafter referred to as the XYZ plan.

The plan brings three parties into a contractual agreement, namely (1) the seller, (2) the buyer, (3) the lender or XYZ bondholder, whose financial support makes possible the contract between the former two.

The XYZ Company pays the seller of the property in cash the price of the property. With this step, the seller is out of the picture.

The rental-purchaser (buyer) enters into a contract with the XYZ Company upon the following terms: He makes monthly rental purchase payments, approximately equal to a rental charge, directly to a trustee, who allocates the sum to (*a*) interest charges, (*b*) taxes, (*c*) life insurance for an amount equal to the rental purchase basis of the property, and (*d*) amortization. The term of amortization is twelve years. No down payment is required. However, if such a payment is voluntarily made, it reduces the financing term correspondingly (a 20 per cent down payment reduces the period to 7½ years). At the end of the financing period, the insurance policy is turned over to the rental purchaser for continuance or its cash value at that time, as he may wish. Should he die during the term of the contract, the property is immediately deeded to his heirs, free and clear of encumbrance.

The XYZ bondholder has as security a real estate lien plus trusteed funds set up to meet the redemptions as they fall due. Irrespective of the condition of the real estate market, and consequently of any adverse influence that a deflated market may have on the real estate lien as security to the bond, the trusteed funds plus whatever value the building site may have are sufficient to meet the redemptions at the end of twelve years, and leave a considerable surplus. Disregarding property and site values entirely, the funds, at an accumulation of slightly better than 4 per cent, can themselves meet the redemptions in full.

In the present depreciated mortgage market, the plan could bring to an end the difficulties inherent in any reorganization, for it is applicable to mortgages whole or certificated as well as to properties.

Philadelphia, Pa., April 17, 1935. WILSON WOELPPER, Management Engineer.

Fine Material in Rockfill Dams

Sir—Your correspondent Mason D. Pratt criticised the selection of material for San Gabriel Dam No. 2 (*ENR*, March 28, 1935, p. 461), asserting that a more stable structure could have been built at less cost with a fragile rock located nearer the site.

Although I have not been connected with the San Gabriel Dam, it seems questionable to me whether the rejected fine material would have made a solid fill less liable to settlement. The remedial measures advised by the consulting board and later put into effect would indicate that too much fine material was used or, at least, improperly placed. At any rate Mr. Pratt's general statement that "Experience with this and several other large rockfill dams indicates clearly that a binder of fine material is necessary" is, I believe, misleading and not the expression of majority opinion among engineers who have had experience with rockfill dam construction.

The stability of dams composed of mixed materials or of rock with wide variation in sizes depends largely on ideal grading of the material in place and thorough compacting. In an earthfill dam or one composed mainly of earth the attainment of both stability and imperviousness is relatively easy, but in a rockfill dam with variable amounts of fine material it is not possible with the aid of practicable construction methods to realize a near approach to ideal grading of the dumped fill material. Anything short of nearly perfect grading or distribution of fine material is likely to cause large and irregular settlement, with consequent leakage through the relatively pervious mixture. To avoid the risk of this, it becomes necessary to exclude fine material as nearly as possible and properly distribute the small quantities which are impossible of easy separation at the quarry.

If this is accomplished and hard rock is used, with some attention to grading of sizes, there can be no serious settlement. Any leakage can pass freely through the dam, and rainfall of any intensity cannot induce settlement.

In constructing a rockfill dam in layers of some 25-ft. thickness by dumping from trucks, a thin layer of fine material forms over the area from which dumping takes place. This layer may be a few inches to 3 or 4 ft. in thickness, and is unavoidable in the process of dumping because the large pieces of rock roll toward the bottom of the slope and the fines drop off the truck last and remain at the top. Some additional fine material is sometimes placed over the dumping area, to facilitate the movement of trucks. There is no practical or economical method of placing fines in a rockfill of large-dam proportions to act as a binder, implying, as this does, thorough filling of all the voids in the structure.

Layers of fine material accumulating in the manner shown can be a source of weakness, but if the fine material is carefully scattered into the voids lower down by a strong jet of water, the final settlement of the large durable rock will take place quickly. Apparently this sluicing of fines had not been done during construction of San Gabriel No. 2 but was later recommended by the consulting board. So far, the results of the jetting operations on the nearly completed dam indicate that almost final settlement can be insured at once by spreading the fines in this manner.

A few years ago I was engaged on a power project in northern California, which included the Bucks Meadow rockfill dam, and on this work care was taken to reject large quantities of fine material and also to sluice the smaller quantities that reached the dam. This has proved to be justifiable practice. No attempt was made to use the fine material as a binder, as Mr. Pratt suggests, but the effort was rather to prevent its uneven placement and to scatter it into large voids, thus permitting the heavier pieces of rock to settle closely together.

Burlingame, Calif., April 8, 1935. RUSSELL G. HACKETT.

ENGINEERING NEWS-RECORD

Volume 114, No. 19

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Editorial and Publishing Offices at 330 West 42d Street, New York

May 9, 1935

Unauthorized Construction

FIRST interpretation of the government's executive powers under the Recovery Act, the Supreme Court's decision on Parker Dam, is clarifying, even though less lucid than some prior announcements of the court on problems of the much-discussed Colorado River. The decision says that the construction is unauthorized; the necessary preliminary of affirmative authorizing action by Congress was omitted. While the President's powers under the Recovery Act were invoked, the court appears to hold these powers not directly applicable, as the agreement for building the dam was consummated before passage of the Recovery Act. The absence of Congressional authorization therefore is the decisive point. The lack should be easily rectified. It is to be hoped that the work will soon be given proper warrant, for its utility and eminent desirability have nowhere been questioned. The decision, moreover, disposes of the basic factor of dispute, namely Arizona's claim to final authority over the river; for the court clearly declares that the United States has power to undertake the work regardless of Arizona claims so long as its power is exercised in the manner prescribed by Congress itself. The fundamental issue being thus settled, the work should promptly be given authority to proceed in legal manner.

Limits of Power

THE PARKER DAM DECISION answers a question that has been in doubt ever since the Recovery Act was passed and the government undertook the construction of several large projects not previously authorized by Congress. The question is whether the Recovery Act empowered the President to ignore the practice long ago prescribed by Congress of having all projects for the development of navigable streams recommended by the Chief of Engineers before their construction is undertaken. The court says no; the Recovery Act neither expressly nor by implication abrogated that requirement, but merely permitted executive financing of projects recommended by the Chief of Engineers without waiting for approval by Congress. This finding may bear on some current projects other than Parker Dam; applied in literal scope, for example, it raises question as to how far the TVA may go in altering the army engineer plans for development of the Tennessee River. Its application may extend also to the new relief works act, and if so it presumably means that such river and harbor work as is financed under this act must be taken from among work on the Chief of Engineers' program, or else must be specifically authorized by Congress. Many have questioned the assumption on the part of the Administration that Congress under the Recovery Act delegated to the President almost unlimited powers to finance new construction. The Parker Dam decision of the Supreme Court covers only works in aid of navigation, but as applied to that wide field it is clear that the President's power is limited to expediting construction of only those projects that have been approved by the army engineers. By implication, the decision may be considered to affect all projects normally requiring an act of Congress authorizing construction.

Men and Mechanization

FIGURES difficult to grasp confront the construction engineer who attempts to appraise in work units the huge volumes listed in the description of progress on the Fort Peck Dam, elsewhere in this issue. A hydraulic fill that will contain 100,000,000 cu.yd., stripping to the amount of 4,000,000 cu.yd., 13,000,000 cu.yd. of spillway excavation, nearly five miles of railroad-size tunnel and over 1,000,000 cu.yd. of concrete, all combined to create a single structure for water storage, strain ordinary comprehension. Considering the isolated location of the work away from railways and even roads, away from sources of power and without places for men to live, the remarkable fact is that any progress in bringing the ultimate structure into actual form was possible in a short twelve months, including the long, cold Montana winter. It was made possible only by bringing into action all the resources of invention, of business organization and of technical skill that engineering and contracting and the equipment manufacturers have created in a generation of great public and private construction. This is a vital fact to remember at a time when distress is causing the thinking of many in authority to revert to older orders of construction procedure. Fort Peck Dam progress is the child of skilled generalship plus ultra modern mechanization. Without this parentage the great Missouri River dam construction would not be in the condition that it is and would not be giving employment to so many men needing work in so many fields of industrial labor. In no great engineering work, not even excepting the marvel of Boulder Dam, have mechanization and organizing ability more thoroughly proved in greater degree their vital importance in speeding the enlistment of labor.

In Truer Proportions

DROUGHT AND DUST have been big news this spring, just as storm, disaster or famine are big news at any time. But the dust-storm reports have at times tended to lose a sense of proportion, to swim in superlatives. What is the truth about these reports? Is the drought worse than ever? Are the dust storms unprecedented? Must an empire be abandoned and returned to range or desert? A considered analysis, especially prepared for this issue, by an agricultural authority familiar with the affected territory, outlines the situation in truer proportions. The drought this year has been worse in about one-tenth of the territory that suffered last year. Dust storms that originate in this same territory—western Kansas, eastern Colorado, northeastern New Mexico and the panhandles of Texas and Oklahoma—have been more widespread than ever before but are not unprecedented in severity, for in this territory local dust storms are as common as rain storms. Only tenant farmers who are paid in crops have migrated elsewhere. Even the loss of crops is quite unimportant from a national standpoint. In short, we contemplate not a national calamity, not even a permanent disaster for the area affected, but a territorial drought of major proportions. Professor Throckmorton, in his article (p. 669) which makes this plain, points out that improved farming methods would

have reduced the damage greatly and, if adopted in the future, will serve as a stabilizer. Rain is all that is needed now—and though, as some wag has remarked, that is all that hell needs, the fact stands nevertheless that the region has had rain and good crops during many years and will have them again. The seriousness of the present situation is not to be minimized, but the facts should be viewed in their true proportions.

For Wider Roads

NO DIMENSION of the modern road appears so frightening to the highway planner as width. He dodges formal commitment to specific figures of width, whether of right-of-way or of travel lanes, in all his general statements of desirability of amplitude. In an excellent report (to be reviewed next week) of the State Planning Commission of Maryland on a ten-year plan for highway improvement, the reporters get no farther than to urge a "generous" right-of-way and to point out that there is growing opinion that traffic lanes should be "somewhat wider" than 10 ft. This lack of boldness in using definite figures is not complimentary. In no respect is greater hazard to driving safety presented than in present narrow traffic-lane widths—indeed more generally in narrow widths of roadway, shoulders, ditches and slopes. Not even alignment and sight distance are in greater need of improvement to safeguard travel by highway. On main roads planned for modernization there ought to be no less than 100 ft. between right-of-way lines, and travel lanes ought not be less than 11 or 12 ft. wide, whether for speed traffic or for trucking. A bold stand by highway engineers for greater road widths would be timely. Width deserves preference over the additional mileage built to the current narrow standards.

Avoid the Guild System

THE second annual report of the Engineers' Council for Professional Development has just been published. It shows commendable progress in the matter of student selection and guidance, in plans for accrediting engineering schools and in aid for junior engineers; but it devotes a disconcerting amount of attention to a subject of questionable value to the E.C.P.D. movement—certification into the profession.

The rounding out of the council's program that is now taking place, and some other recent happenings relating to the engineering profession, raise question as to whether the profession's commendable moves toward broadening the development of individual members may not bring with them some of the unfavorable aspects of the guild system. Vocational guidance for high-school students, student selection, accrediting engineering schools, raising and strictly limiting the requirements for registration as professional engineers, and laying down a program of training as a preliminary to acceptance in the higher grades of the technical societies, all tend toward improving the training of the average engineer. On the other hand, the grade of material from which the professoin is recruited may be definitely lowered by setting a limit upon the number of students who take up engineering, as some have proposed, or by attempting to restrict the profession to those who can enter through the college gateway. These features of the guild system tend toward mediocrity rather than improvement.

It remains to be demonstrated that all the young men who went to engineering schools with a definite feeling that engineering was the proper field for them have turned out to be capable engineers, or conversely, that capable engineers have not been made of men who showed no special aptitude for engineering upon entering college. And most emphatically, it remains to be shown that those who would select boys for their special fitness to enter the engineering career are competent to be entrusted with so responsible a decision. Hence, until we know more about these matters, too much dependence cannot be placed on methods of student selection.

Nor should too high a value be placed on scholastic accomplishment, lest there be developed a system that turns out mathematicians skilled in the minutiae of engineering design but lacking the sound judgment and correct sense of engineering values that are essential to an engineer.

Technical college training will not make an engineer; what the training does is to stimulate the natural ability and supplement it with organized knowledge. When so considered, it becomes evident that the profession's objectives in laying down a system of training should be these: first, to make training in the fundamentals of engineering available to the greatest number of those who appear to have natural inclinations in that direction; second, to see that the scholastic training is broad and not so bound to tradition as to limit original thinking; and, finally, to supplement the scholastic training by laying down a program of study for the years immediately following graduation, thus rounding out the training of the young engineer and keeping him from falling into a narrow rut.

To return to the matter of certification: Both the report referred to and the views expressed at the recent E.C.P.D. meeting in New York make it apparent that at least some of those who are directing the development of the council look upon certification as the chief objective of the organization; they would have it the open sesame to registration by state boards of engineering examiners, to technical society membership and to master's degrees in the colleges.

Here is the guild system at its worst—when those within a profession set up an agency removed from public control which can keep out any or all who would seek to come in!

As a substitute for registration by state examining boards the plan is particularly bad and is a perversion of the original idea back of the E.C.P.D., that of rounding out and broadening the training of engineers. To put the situation briefly, the state's one concern with engineers is public safety; it therefore seeks only to determine whether a man has the *minimum* qualifications warranting practice as an engineer. The council, on the other hand, is interested in assuring to each engineer the *maximum* qualifications for success in rendering professional service to the community. Certification by E.C.P.D., therefore, if adopted at all, should be of quite different character from that required for registration by state examining boards; it should be an honor to which all may aspire but not all obtain. But it should not seek to take the place of the state's certification.

These are dangers that lie in the path of the Engineers' Council for Professional Development. They are not insurmountable. All that is needed is to recognize them at this early stage of its progress and guard against them. If the organization is directed toward professional development, it can succeed; if it is diverted into creating a guild system, it will fail.

CURRENT NEWS

Disagreements on Policy Delays Start of Relief Works Program

(Washington Correspondence)

SHARP disagreement on policy regarding the character of work to be undertaken is primarily responsible for delay in the relief works program. One month after Congress appropriated the $4,000,000,000 fund, President Roosevelt still is trying to develop a list of projects that will combine utilitarian construction with speed in execution.

A wide divergence of views was revealed by the first meeting of the Works Allotment Division on Tuesday. Administrator Ickes, the chairman, desires to put the emphasis on projects which constitute productive public improvements. Harry Hopkins, FERA Administrator and head of the new Progress Division, is equally emphatic in his preference for work of a type that will provide quick employment for the largest number of men. Mr. Ickes counts heavily on the indirect employment created by public works. Mr. Hopkins thinks in terms of immediate employment of men now on relief rolls.

A majority of the Works Allotment Division hold with Mr. Ickes. Practically all of them are from established agencies with definite ideas regarding the use of this money to the best advantage in their particular fields. They likewise appreciate the fact that such a large appropriation is not likely to be made soon again. They have been forehanded and have a certain advantage in fully developed plans on which they are ready to proceed as soon as allotments are made and labor is supplied, either from relief rolls or the CCC.

President Roosevelt is seeking to reconcile the conflict in the Works Allotment Division by insisting that much heavy construction work can be completed within one year by stepping up time schedules. To reach his goal of putting 3,500,000 men on jobs within that length of time, President Roosevelt may be forced, however, to approve work projects more nearly resembling the old CWA program, although better performance is expected on public works than was the case in PWA.

Duties of divisions still vague

Apart from the time required to select projects that will comprise a well-balanced program and, by location, provide employment where it is most needed, the necessity for careful drafting of executive orders translating into specific terms the broad powers vested in the President by Congress is another reason for the delay in actually getting work started. The President is, in fact, in process of writing his own law in orders such as those which created the Resettlement Administration under Rexford G. Tugwell and the rural electrification program under Morris Llewellyn Cooke. Both of these organizations will work in close cooperation in the rehousing of destitute farmers and in control of soil erosion where electric power for pumping water is a necessary adjunct to the program.

On non-federal projects which the states and cities will continue to carry out under the supervision of PWA the situation is still confused. The requirement for completion within one year is a hard and fast rule so far as initiating a project is concerned but Administrator Ickes has persuaded the President to make allotments for one year's work without obligating the work relief appropriation for the balance needed.

Size of grants not yet determined

Mr. Ickes has still to convince the President that a policy of liberal grants, above the present limit of 30 per cent if need be, would actually return a larger amount of money to the Treasury, by bringing forward more projects, than the President's disposition to finance non-federal projects by 100 per cent loans. On the other hand, loans at a low interest rate probably will not cost the borrowing municipality any more, according to the President, than a grant of 30 per cent combined with a loan for the remainder at 4 per cent, the rate now charged by PWA.

Administrator Ickes apparently has accepted the President's opinion that the amount of the grant, if any, should be determined by negotiation in each case, although he does not believe that this is conducive to good administrative practice.

Procurement division purchases

The total allotment for non-federal projects will, according to Mr. Ickes, depend solely upon the number of applications which are approved. He also expressed the belief that the new procurement division will operate principally on big federal projects on which bulk purchases would represent a saving, and that on non-federal projects the contractors would be allowed to purchase their own materials.

New divisions set up

By an executive order the President set up the Division of Applications and Information in the National Emergency Council. At the same time the Works Progress Administration and the Advisory Committee on Allotments, formerly referred to as the Works Allotment Division, were also created. As constituted by the executive order the allotment committee does not include a division for grade crossing elimination, which the President had previously announced would be placed in the Bureau of Public Roads.

The President is much impressed by the state-wide plan of public works presented by Governor LaFollette, of Wisconsin. He foresees the possibility of its adoption on a basis under which the federal and state governments would each contribute to its execution at a cost per unemployed person representing a saving to both over present methods of relief administration.

Allotments of Two Billion Segregated by New Board

The Advisory Committee on Allotments set up by the President under the relief works act, meeting in Washington on May 7, made segregations of half of the four billion dollar relief works fund. The following allocations were announced:

"Highways, roads, streets and grade-crossing elimination, $400,000,000.

"Rural rehabilitation and relief in stricken agricultural areas, and water conservation, trans-mountain water diversion and irrigation and reclamation, $250,000,000.

"Rural electrification, $50,000,000.

"Housing, $225,000,000.

"Assistance for educational, professional and clerical persons, $150,000,000.

"Civilian Conservation Corps, $300,000,000.

"Loans or grants or both, for projects of states, territories, possessions, including subdivisions and agencies thereof, municipalities and the District of Columbia and self-liquidating projects of public bodies thereof, where, in the determination of the President, not less than 25 per centum of the loan or the grant, or the aggregate thereof, is to be expended for work under each particular project, $450,000,000.

"Sanitation, prevention of soil erosion, prevention of stream pollution, sea coast erosion, reforestation, flood control, rivers and harbors and miscellaneous projects, $175,000,000."

The committee also took up the matter of geographical distribution of the money. Harry L. Hopkins submitted a map tentatively dividing the country up into 320 employment areas.

Code for Heavy Construction And Railroad Work Approved

A supplementary code of fair competition for the heavy construction and railroad contractors has been approved by the President. The code, a subdivision of the general contractors division of the construction industry, carries the general wages and hours provisions of the master construction code. With the exception of watchmen, who may work 56 hours per week; job and field clerks who have unlimited hours but a six-day week; and supervisors getting more than $35 a week, the 40-hour week and the 40c. an hour minimum wage prevail.

St. Louis Memorial Project Aided by New State Law

Governor Guy B. Park of Missouri has signed a bill which provides that the Board of Aldermen of a city of 400,000 or more may call an election upon petition of 1,000 or more taxpayers to determine whether the city shall issue bonds to assist the United States government in the establishment of parks commemorating notable historic events. There is a provision that the amount of such bond issue shall not exceed $7,000,000 or one-fourth of the amount the federal government spends on the memorial project. The bill applies chiefly to the city of St. Louis and is intended to cover the proposed Jefferson Memorial project on the St. Louis River which has been estimated to cost about $30,000,000.

California Continues Work On Colorado River Aqueduct

The United States Supreme Court ruling, which dismissed the government's suit to restrain the state of Arizona from interfering in the construction of Parker Dam on the Colorado River, will have no effect on Colorado River Aqueduct construction by the Metropolitan Water District of Southern California, according to statements of district officials at Los Angeles. Parker Dam is being built by the federal government and its construction concerns the government and the state of Arizona. The water district has an agreement with the Reclamation Bureau in the event Parker Dam is built to reimburse the government to a certain amount. Should the suspension of work on Parker Dam become permanent the district has plans for pumping its allotment of water directly out of the river and into the aqueduct line.

Herring Joins Joint Secretariat Of Public Works Organizations

Frank W. Herring, for the past five years assistant editor of *Engineering News-Record*, on May 1 became assistant director of the joint secretariat established by the American Society of Municipal Engineers and the International Association of Public Works Officials following the meeting of those two organizations in Rochester, N. Y., in September of last year.

No director has yet been named. Donald C. Stone, director of the consulting and research division of Public Administration Service, Chicago, has been acting as executive director since the joint secretariat was established last fall. Offices are maintained in Chicago in connection with those of the Public Administration Service.

Mr. Herring, a graduate of Johns Hopkins, has been a close student of municipal engineering and administration for fifteen years. Following several years of design and field inspection work he saw service in the sewer department of Baltimore and the water department of Detroit, leaving the latter connection in 1930 to take up his work with *Engineering News-Record*. In Detroit he had opportunity to carry out an important investigation of filter sands, which laid the foundation for better control of filtration. Later he made a close study of such current problems as sewage treatment and the methods of municipal administration and finance. He is the author of a number of articles on these subjects. He is an associate member of the American Society of Civil Engineers.

Ready-Mixed Concrete Industry To Elect Representatives

The annual election of the seven regional representatives of the code authority for the Ready-Mixed Concrete Industry will be held in Washington, D. C., on May 31, 1935, at the office of the code authority. Separate ballots for each region, with the names of the representatives nominated from those regions, have been mailed to all known members of the industry.

The code authority has requested that all persons who fail to receive a ballot write to the authority asking for such ballots as they need.

Cutting Bid Prices On Federal Work Found Ineffective

IN A REPORT to the President on April 8 the National Industrial Recovery Board set forth some preliminary conclusions regarding the effects of executive order No. 6,767, dated June 29, 1934, permitting the quotation of prices to government agencies of not more than 15 per cent below the bidder's prices filed with the code authority for his industry.

The order had been issued on the complaint of purchasing agents of municipal, state and federal governments against the recurrence of tie-bids which they claimed were the result of the open price filing under manufacturing and distributing codes. Since most governmental agencies are under the obligation of awarding contracts to the lowest bidder these tie-bids created a difficult situation and the executive order was an attempt to overcome this difficulty.

Code authorities in the construction industries petitioned NRA to recommend rescinding the order as it had the effect of putting governmental agencies in the "most favored buyer" class and encouraged governmental purchase of supplies and materials and the use of day labor for construction.

The order provided that the National Recovery Administration should make a study of the effects of the order upon the maintenance of fair competition in sales to public and private consumers. The Research and Planning Division, accordingly, sought to answer a number of questions, including the effect of the executive order on public purchases, on the number of tie-bids, the number of tie-low bids (uniform low bids) and on prices. The report indicates that really complete information could not be obtained. Out of a total of 85 sets of contracts studied, all relating to purchases by the procurement division of the Treasury and the bureau of supplies and accounts of the Navy, 41 showed an increase in tie-bids after the order was issued; 10 showed little or no change, while 34 showed a decline. Considering the entire period covered by codes, a count by the industries studied showed that the percentage of tie-low bids had decreased in 31 industries and was the same in 15.

The report made no mention specifically of the construction industry's complaint except the general conclusion that the discount permitted by the order had actually been used in relatively few industries covered by the study.

Washington Highlights

By PAUL WOOTON

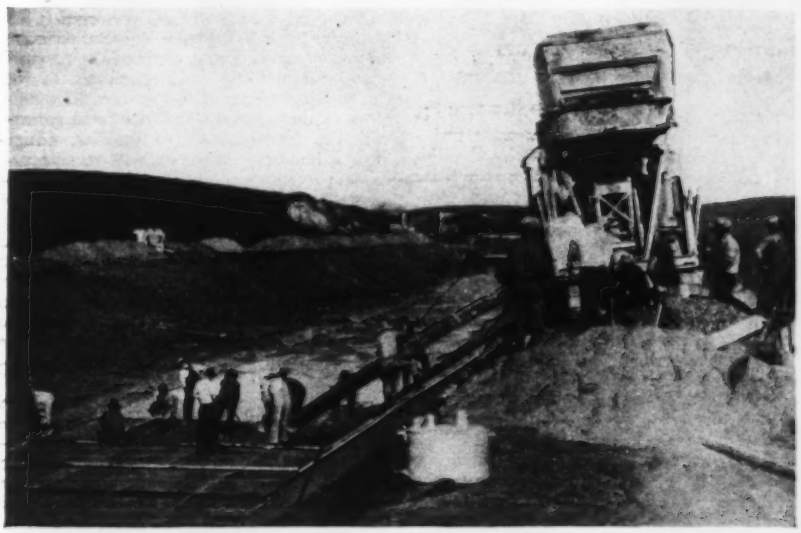
With recovery overdue, economists see many signs of an approaching major upswing in general business.

The government already has purchased over 5,000,000 acres of submarginal land and hopes ultimately to move 30,000 families to good farms.

Government development of gold and silver mines and of deposits of other noncompetitive or deficiency minerals has been approved by Senate and House committees.

Pleas by the cotton textile industry for elimination of the processing tax bid fair to go unheeded. The Cabinet committee seems to feel that the industry is suffering chiefly from other ills and is losing out to automobiles in the fight for a portion of the consumer's dollar.

Prof. O. M. W. Sprague, testifying before a Senate committee, said the two billion dollars of bonus greenbacks would not dilute the currency much, but the real danger would be the blow to confidence if such an unsound proposition is allowed to reach the statute books.



CANAL LINING WORK IN CALIFORNIA

Lining a large irrigation canal of the Modesto Irrigation District in California. Concrete for half the floor and for the side slope is supplied from a tractor-mounted mixer traveling on the canal bank. The work is being done with PWA funds.

Water Tank of Scrap Material Collapses When Filled

A water tank of 68,000 gal. capacity at the town of Gordo, Ala., collapsed on April 23, apparently due to the failure of one of the legs of the supporting tower.

Exact details as to the tank and tower are lacking, but it is reported that the tank itself was of heavy steel plate, being formed by inverting the upper end of an old stove of an iron furnace. The tower was made of what appeared to be old bridge compression members, two 12 in. channels with a plate on one side and lacing on the other side. The diagonals were small rods.

Connections at the column splices were bolted, the holes being irregular in shape and appeared to have been burned with a torch. Generally, they were considerably larger than the bolts. The collapse appears to have been caused by the failure of one of the column splices.

AGC Advisory Board Condemns Work of Code Authority

The advisory board of the Associated General Contractors at its annual meeting passed resolutions condemning the NRA for its failure to carry out its obligations to the construction industry. The board also recommended the appointment of a national safety director and advocated the employment of only skilled operators for construction equipment.

The delegates favored the $4,880,000,000 relief works program but at the same time warned the government against discrimination against small industry. The warning came as a result of the opinion by the board members that the administration of relief works favored big business.

Endorsement of the stand taken by Henry I. Harriman, retiring president of the U. S. Chamber of Commerce, that the government should not interfere with private industry was expressed by the advisory board. Also a plea was voiced that the relief works activities be carried out by contract rather than by day labor.

Cooling Water in Sewers Makes Trouble at Columbus

Damage estimated at $100,000 annually is being done to sewers and the sewage treating system of Columbus, Ohio, by the discharge into the sewers of large quantities of water high in sulphur content from cooling systems in the city. The water comes from 103 wells used by factories, stores and theatres and is estimated to amount to 17,000,000 gal. per day, or about one-third of all the water that comes to the sewage treatment plant.

A report made some time ago to Mayor Worley by City Engineer Paul W. Maetzel, made public recently, revealed that the cost of treating this water at the sewage disposal plant amounts to about $10 per 1,000,000 gallons treated. Hence that cost alone amounts to $51,500 yearly. In addition, engineers have figured that damage to the sewers by water of high sulphur content amounts to $50,000 each year, making a total cost to the city of more than $100,000.

It has been proposed that a tax be placed on this use of well water for cooling purposes.

Flood Control and Coast Erosion Under New Federal Agency

By an executive order on May 1 President Roosevelt created the Resettlement Administration under Rexford G. Tugwell, giving him the power of administering projects for flood and seacoast erosion control. Another executive order transferred from the FERA the money, property, personnel and records of that organization to the new administrative agency. The balance of all appropriations allotted to the FERA are to be transferred to the Resettlement Administration and are to be used for the same purpose for which they were originally allotted.

It has not been definitely determined whether Administrator Tugwell's power gives him complete authority over all seacoast erosion projects and such flood control projects as those on the Mississippi, or whether he will merely be empowered to initiate and administer such projects as are necessary in resettling families in rural and suburban areas.

The duties and functions of the Resettlement Administrator as set forth by the President are:

(a) To administer approved projects involving resettlement of destitute or low-income families from rural and urban areas, including the establishment, maintenance, and operation, in such connection of communities in rural and suburban areas.

(b) To initiate and administer a program of approved projects with respect to soil erosion, stream pollution, seacoast erosion, reforestation, forestation and flood control.

(c) To make loans as authorized under the Emergency Relief Appropriations Act of 1935 to finance, in whole or in part, the purchase of farm lands and necessary equipment by farmers, farm tenants, croppers, or farm laborers.

American Standards Association To Correlate Building Codes

The American Standards Association has organized a building code correlating committee to carry on the work of the recently disbanded building code committee of the U. S. Department of Commerce. The purpose of this special committee is to formulate the fundamentals of building design into a building code that will receive national acceptance. Architects and engineers have been hampered by conflicting building code provisions which adversely affected the cost or design of structures. An effort will be made to correlate the best features of various building codes into a uniform code and to have this code accepted by municipalities throughout the country. Various sub-committees will be directed by and report to the main correlating committee.

Among the societies which have been invited to participate in the work of the correlating committee are: American Institute of Architects, American Public Health Association, American Society for Testing Materials, American Society of Civil Engineers, Associated General Contractors, and the Federal Housing Administration. Others have been proposed and provision is made to include a still larger number.

East River Vehicle Tunnel At New York Authorized

A bill authorizing the Board of Estimate and Apportionment of the city of New York to create the Queens-Midtown Tunnel Authority has been approved by Governor Lehman of the state of New York. The three members of the Tunnel Authority are to be appointed by the governor. The act authorizes the Tunnel Authority to construct a vehicle tunnel under the East River at New York from the borough of Manhattan to the borough of Queens and a connecting tunnel under Newtown Creek to Brooklyn.

Construction of the tunnel or tunnels is to be financed through the sale of bonds secured by a pledge of the income from tolls and other revenue.

Area Agreements Under Code Make Little Progress

Construction code area agreements, which fix maximum hours of labor, minimum rates of pay, and other conditions of employment within specified areas are slow in being formulated and submitted for approval. According to the last compilation 34 area agreements have been approved by President Roosevelt. Of these 22 are in the painting division, five in the electrical contracting division, three in the mason contracting division, two in the plastering division and one each in the tile and plumbing divisions.

The recently approved agreements show a tendency to be state-wide in application. Under Agreement No. 19 for the painting, paperhanging and decorating division, the entire state of Rhode Island is covered. This agreement carries a 40-hour week and an 80c. per hour minimum rate for skilled workers. The endeavor to attain state-wide application is also shown in Agreement No. 21 for the same division in California. Originally this agreement was proposed to cover the entire state but as the representation of employers and employees in the rural areas was not considered as being representative of those areas the agreement, as approved, covers only the metropolitan districts of Los Angeles, San Francisco, Sacramento, San Diego, San Jose and all the cities of 10,000 population or more, and the territory within a radius of three miles of the corporate limits of such cities. A 35-hour week and a minimum wage of $1 per hour for skilled workers was fixed by this agreement. Since the painting, paperhanging and decorating chapter of the code contains no skilled labor rates, portions of the state not covered by this agreement are not subject to any skilled wage regulation.

Area Agreement No. 2 for the plastering and lathing contracting division was also initially intended to cover the entire state of California, but because of the lack of representation from the rural areas, its application, as approved, covers only the same metropolitan districts as Area Agreement No. 21. This agreement fixes a 30-hour week with a minimum wage for journeymen plasterers or lathers of $1.25 per hour and corresponding rates for other skilled workers. Minimum rates for skilled laborers have been established by the divisional chapter in the areas which are not covered by this agreement.

Road and Grade Crossing Plans Ready: Allotments to be Made Available Soon

(Washington Correspondence)

PRESIDENT ROOSEVELT announced this week that state allotments for road building from the $800,000,000 allocation by the relief works act would be coming along pretty soon. There has been considerable speculation concerning the delay and there is a hint as to the reason in the President's apparent resentment that Congress adopted the Hayden Amendment which ties his hands in the distribution of the fund by specifying that the share of each state shall be determined 10/24 on the basis of population, 7/24 on area and 7/24 on the existing mileage of post roads.

Commenting on this "complicated formula" the President said that the allotments will be so large that in some sparsely populated states the highway program will require more labor than can be supplied from relief rolls. The President did not regard this situation with satisfaction, and conceded that under the law there is nothing that he can do about it, but he declared that the Administration would not be able to spend any money for other work in states where all relief labor is absorbed on road building.

Highway officials point out that by assuming a direct relationship between size of population and unemployment the Hayden Amendment gives due regard to the latter by giving a weight of 10/24 to population as against 8/24 in determining state allotments of federal-aid money. Highway officials also point out that road contractors are required by the relief works act to employ only qualified men from relief rolls and that there will be others who can be taken care of only by other types of work.

The President can, of course, reduce the $800,000,000 allocated for roads by the law, thus reducing in turn each state's share. There is no intimation that he will take such drastic action but in some quarters it is regarded as a distinct possibility.

Projects ready to start

All told there are 9,400 highway projects on which the states are ready to start work. Many are already under contract, awaiting only allotment of funds. Others must wait only on the time required for advertising, usually 15 days. All can be completed within a year.

In reserve is more than $1 billion in 12,700 projects that can be brought up to the work stage in three months to one year. Many of these projects also can be finished in a year's time or less.

Actually the road program will run through two years, as the money available is double the $800,000,000 relief works allocation. Approximately $100,000,000 remains of an appropriation by Congress last year; $250,000,000 of regular federal aid money becomes $500,000,000 when matched by the states.

The highway program includes all types of construction. At least 25 per cent of the funds available will be spent on secondary roads, except in a few states where this network is practically complete. This type of construction moves fast and is soon done.

States plan heavy construction

Many states have developed extensive plans for trunk line routes through or by-passing cities. Such heavy construction takes time, but Wisconsin and Pennsylvania are ready to start $10,000,000 worth of work; New York and Maryland $6,000,000; Illinois $5,600,000; South Carolina $5,000,000; New Jersey $4,000,000; Ohio $3,700,000; Minnesota $3,000,000; California $2,000,000; Connecticut, Oregon, and Texas $1,500,000. Alabama, Arkansas, North Carolina and Washington will spend $1,000,000 or more.

Replacement of weak and narrow bridges is an important feature of the road program in many states. Plans for more than 2,200 jobs costing $86,000,000 are ready for execution. Pennsylvania heads the list with 303 to cost $6,500,000; Ohio is next with 175 bridges to cost $6,000,000.

To eliminate railroad grade crossing, for which $300,000,000 is allocated by the relief works act, plans are ready on 1,756 projects to cost approximately $184,000,000. Plans are in preparation on 2,302, to cost $277,000,000. Early projects include 150 costing $25,000,000 in both Ohio and California; $16,000,000 for 129 projects in New York; $11,000,000 for 43 in New Jersey; $9,200,000 for 87 in Wisconsin; $8,000,000 for 73 in Pennsylvania and a like amount for 75 in Illinois. Plans ready for execution in 26 more states exceed $1,000,000 each. In railroad grade separation and elimination, the states and cities have only to provide any land that may be necessary. Railroads have furnished the assistance of their drafting forces on many projects but the entire cost of construction and materials will be borne by the federal government.

More than a score of states are pushing plans for eliminating congested and dangerous highway intersections. New York and Iowa are ready with plans on projects totaling $4,000,000; New Jersey $2 400,000. California, Connecticut and Massachusetts have prepared plans running in excess of $1,000,000, other states for smaller amounts.

ROAD-BUILDING AND GRADE-CROSSING WORK READY TO START

	Ready in 15 Days to 3 Months Projects		Ready in 3 Months to 1 Year Projects	
	No.	Cost (Millions)	No.	Cost (Millions)
Railroad grade crossing elimination	1,756	$184.3	2,302	$277.5
Highway intersection elimination	161	20.2	182	27.3
Roads, federal-aid, state and secondary	4,645	332.1	6,087	447.5
Trunk line routes and by-passes through cities	621	72.5	1,118	131.2
Bridges	2,285	86.4	3,041	129.1
Totals	9,468	$695.5	12,730	$1,012.6

Philadelphia Can Borrow Money To Improve Water Supply

The Philadelphia Bureau of Municipal Research has pointed out that the city has full legal authority to borrow and spend as much as $32,000,000 for improvement of its water system. The bureau further maintains that the refusal of city officials to make much-needed repairs and replacements in water equipment because of finances is unjustified as the city has a large amount of free borrowing capacity for capital expenditures for the water system.

In addition to its regular borrowing capacity, the city has a special borrowing capacity for revenue-producing projects, and may make loans for projects that will produce enough revenue to meet the interest payment and sinking fund payment.

By using the $1,800,000 surplus from last year the city would be justified in increasing the water debt by about $32,000,000.

Dean Magnusson Advocates Raising Grand Coulee Dam

An increase in the height of the Grand Coulee dam has been recommended in a report to the Washington state planning council by Dean C. E. Magnusson of the University of Washington, chairman of the council's division of power markets.

The report, submitted after a survey of the storage possibilities of the upper Columbia River, particularly in Canada, advocated that the dam be increased to 1,330 ft. This is 30 ft. higher than the present plans for a high dam at the Grand Coulee site and would back up the water over the international boundary, creating a water storage of 6,460,000 acre-ft. None of the present work on the dam would be lost, according to the report, and a high dam must ultimately be constructed if it is expected to store enough water for adequate stream flow regulation.

New York Law Aids State In Use of Federal Funds

Governor Lehman has signed two bills enabling the state of New York to participate in the works program of the federal government. One measure amends the general municipal law to permit any county, town, city or village to issue revenue bonds to the federal government for advances for self-liquidating public works projects.

The second bill creates the New York State Rural Rehabilitation Corporation, which will seek $50,000,000 from the federal fund to provide special forms of relief in rural areas.

The revenue bonds authorized under the first bill will not constitute debts of the municipality and under no condition shall taxes be levied to pay either the principal or interest. When revenue bonds are issued, the municipality will make provision to collect whatever rates may be necessary to make the project self-supporting. The Public Works Administration at Washington has indicated that it will accept these revenue bonds as security for loans to counties, cities, towns and villages for revenue producing facilities.

News Briefs

IMPROVEMENT OF THE MISSISSIPPI RIVER at St. Paul, Minn., to provide a basin nine feet deep, 400 to 1,100 ft. wide for a distance of 2.7 mi. has been recommended to the rivers and harbors committee by Maj. Gen. E. M. Markham, Chief of Engineers.

THE HOUSE OF REPRESENTATIVES has approved a joint resolution creating a special federal commission to determine the feasibility of constructing a Lincoln Memorial Boulevard from the Lincoln Memorial in Washington, D. C., to the Civil War battlefield in Gettysburg, Pa.

CONTRACTORS engaged in the construction of buildings for the state of Arkansas or any of its political subdivisions as self-liquidating projects with funds from the federal government are not required to comply with Act 261 of 1933 of the Arkansas legislature, which stipulates that only residents of Arkansas may be employed.

THE INDIANA HIGHWAY COMMISSION has announced that minimum wage scales for workers on state-financed road projects will be the same as in effect for federal-financed projects. The commission also ordered that all unskilled workmen be residents of the county in which the work is done, whenever possible. Local government services will provide lists of eligibles to contractors.

GOVERNOR JAMES V. ALLRED of Texas has signed a bill raising the limit of revenue bonds which may be issued by the Lower Colorado River Authority from $10,000,000 to $20,000,000. The bill meets requirements of the PWA to make possible the tentative allotment of from $17,000,000 to $20,000,000 for purchase of land, completion of the Buchanan Dam and construction of other power dams on the Colorado River.

THE KENTUCKY STATE HIGHWAY COMMISSION has increased its budget for the year April, 1935-March, 1936, by $1,790,000. This increase was made possible by the state tax commission's report that there will be increased revenue for the highway department. It is expected that gasoline taxes will increase by $2,814,000, but that motor license taxes will be reduced by $1,049,000, resulting in a surplus that can be expended for maintenance and new construction of highways.

ACQUISITION OF A SITE for the proposed $30,000,000 Thomas Jefferson Memorial project on the river front between the Eads and Municipal bridges at St. Louis has been approved by the board of aldermen provided the federal government will furnish the funds for the construction work. It has been estimated the site would cost not more than $8,000,000. The voters of the city have yet to pass a bond issue to provide money to buy the site.

THE BOSTON PLANNING BOARD, through its chairman, Frederic H. Fay, has submitted a report to the city council to the effect that railroad electrification in the Boston area would cost about $100,000,000; that it would not be possible for the return to meet the carrying charges; also that Diesel-electric locomotives would afford a more economical solution of the problem of rail transport on the suburban lines of the Boston & Maine, New Haven and Boston & Albany systems at the Hub.

RECORD FLOODS on the Athabaska and Pembina rivers in Alberta have swept away two bridges. Dammed by ice jams the rivers have risen to heights from 12 to 15 ft. over previous high water marks.

AN INTERESTING FEATURE in the Canadian government's public works scheme for the relief of unemployment is a provision of $1,000,000 to finance 180 small geological survey and prospecting parties which will be sent out during the coming summer into unsurveyed territory in all the provinces of Canada. In addition to searching for gold and other precious metals the parties will be instructed, where necessary, to search out also sources of water supply, and other features of general significance.

PUBLIC WORKS ADMINISTRATOR ICKES reported further progress on the slum elimination and low-cost housing program with the announcement that bids were opened on the Indianapolis community housing project on May 7. Results of the bidding are not yet known. The Indianapolis project is the fifth federal development on which construction bids have been opened in the last five months. Two of these projects are already under construction; the Techwood and University projects in Atlanta.

SOCIETY CALENDAR

NATIONAL FIRE PROTECTION ASSOCIATION, annual meeting, Atlanta, Ga., May 13-16, 1935.

AMERICAN INSTITUTE OF ARCHITECTS, annual convention, Milwaukee, Wis., May 28-30. THE PRODUCERS' COUNCIL will hold its 12th annual meeting in connection with the Institute meeting.

AMERICAN SOCIETY FOR TESTING MATERIALS, annual meeting, Detroit, June 24-28.

AMERICAN SOCIETY OF CIVIL ENGINEERS, annual convention, Los Angeles, July 3-5.

NEW ENGLAND WATER WORKS ASSOCIATION, annual meeting, New London, Conn., May 16.

NEW YORK STATE SOCIETY OF PROFESSIONAL ENGINEERS, annual meeting, New York, May 18, 1935.

THE PASSAIC COUNTY ENGINEERING SOCIETY recently celebrated its fifteenth anniversary. The officers elected were: V. J. SCANLON, president; F. W. LOEDE, vice-president; A. L. BICKFORD, secretary; A. VERDUIN, treasurer.

STATE EXAMINATIONS for registration of engineers and land surveyors are scheduled to be held in the near future as follows:

MINNESOTA—By the Board of Registration for Architects, Engineers and Land Surveyors at St. Paul, Minn., June 17, 1935.

FLORIDA—By the State Board of Engineering Examiners. Examinations held in each county seat where applications are filed, June 6-8, 1935.

NEW YORK—By State Board of Engineering Examiners at Albany, Buffalo, New York and Syracuse, June 24-26, 1935.

SOUTH CAROLINA—By the State Board of Engineering Examiners at Columbia, July 9. Applications must be filed with the secretary ten days in advance of the meeting.

Personals

JOHN CHIPMAN, for six years research engineer in the department of engineering research at the University of Michigan, has joined the research staff of the American Rolling Mill Co., Middletown, Ohio.

MALCOLM PIRNIE, consulting engineer, New York, has been appointed to the engineering advisory board of New York University. Mr. Pirnie is vice-chairman of the Construction League of America.

LAWRENCE PRATT, recently with the engineering department of the city of Tucson, Ariz., has been appointed inspector of maps of the Tennessee Valley by the U. S. Geological Survey with headquarters at Chattanooga, Tenn.

E. P. HAPGOOD, Anaheim, Calif., city engineer, has been appointed a member of the board of directors of the Metropolitan Water District of Southern California to succeed the late O. E. Steward as Anaheim's representative on the board.

JOSEPH C. JONES has become associated with Sanderson & Porter, engineers, New York. Mr. Jones was with Ford, Bacon & Davis, Inc., until March 1, and formerly with Thomas E. Murray, Inc., engaged in activities connected with industrial and public utilities works.

C. H. CRAWFORD, consulting engineer, New York, has been appointed Forest Products Administrator by the NIRB to coordinate administrative activities in the lumber and timber products code. Mr. Crawford has been deputy administrator in the section handling the lumber code.

ORMOND A. STONE of Pasadena, Calif., has been appointed chief engineer for the Los Angeles County Relief Administration. He succeeds RALPH B. SMITH, chief engineer since April, 1933, who is to take over new duties with the State Relief Administration in San Francisco. Mr. Stone has been engaged in engineering work in Los Angeles and vicinity since 1910.

A. M. TRUESDELL, of Seattle, Washington, bridge engineer and former instructor at the University of Washington, left Seattle May 1 for Anchorage, Alaska, to become bridge engineer for the Alaska Railroad Commission. Mr. Truesdell was bridge engineer for the city of Tacoma, Washington, from 1928 to 1932 and has since worked for the Reclamation Bureau at Coulee Dam.

CHARLES R. GOW has been appointed head of an advisory board by Mayor Mansfield of Boston, Mass., to supervise the drafting of an extensive program of public improvements to be submitted to the federal authorities for allotments under the work-relief fund. Other members of the board will be THOMAS F. SULLIVAN, chairman of the Boston transit department, and W. STANLEY PARKER, practicing architect and vice-chairman of the Boston planning board.

JEROME RAPHAEL, a student at Massachusetts Institute of Technology, won first prize in the seventh annual bridge design competition held by the American Institute of Steel Construction. ALEXANDER MATTHEWS, JR., a student at the Yale School

of Engineering, won second prize. First Honorable Mention was given to DAVID HIAT of New York University, and Second Honorable Mention to FRED A. THOMPSON, JR., of Iowa State College. The problem was to design a steel grade crossing elimination bridge carrying a highway over a railroad and another highway parallel to the railroad.

J. C. BAKER, state highway director for Arkansas, has been reappointed to that position by Gov. Futrell for a term of two years. The appointment was made under a recent law which provided that the director should be appointed by the governor instead of being selected by the commission and which makes the director administrative head of the department. Mr. Baker was elected director by the commission a year ago.

PROF. THORNDIKE SAVILLE has received the appointment as associate dean of New York University College of Engineering. Since 1932 Prof. Saville has been head of the department of hydraulics and sanitary engineering. Prior to his coming to New York University he was professor of the same subjects at the University of North Carolina and chief engineer of the North Carolina department of conservation. During the past year Prof. Saville has been special consultant to the U. S. Geological Survey and directed a study of Mississippi floods.

HENRY W. LOHMANN has resigned as vice-president of the general contracting firm of James Stewart & Company, Inc., New York City. He will retain his association with the company as a director and special consultant. Mr. Lohmann's resignation was prompted by ill health. Mr. Lohmann had been with James Stewart & Company, Inc., 46 years, joining the company in March, 1889. Recently he has been vice-president in charge of all estimating and statistical work, and has been active in the direction of many of their larger building operations.

Obituary

J. FRANK CROWTHER, 71 years old, a retired contractor of Baltimore and former head of the municipal department of buildings, died on May 3.

JOHN I. HUDSON, aged 72, former city engineer of Portsmouth, died recently at Columbus, Ohio. Mr. Hudson, an honor graduate of Virginia Military Institute in 1885, served in the Ohio senate 1912 and 1916.

ARTHUR O'BRIEN, highway superintendent of Oneida County, N. Y., since 1912, died in Utica, April 25 following a brief illness. Born in Forestport, N. Y., in 1870, Mr. O'Brien entered state service as assistant engineer in 1894 and was engaged in canal and highway work for seven years. He was appointed city engineer of Utica 1908.

CONSTRUCTION STATISTICS OF THE WEEK

ENGINEERING CONSTRUCTION awards for the week total $17,460,000, of which $4,467,000 is private work and $12,993,000 in public construction. Of the public awards, $3,054,000 is federal and $9,939,000, state and municipal. This total is slightly lower than last week due to lower public awards.

Highway awards at $3,901,000, bridges at $982,000, waterworks at $713,000, and commercial buildings at $1,236,000 all dropped below last week, while increases are recorded in public buildings at $3,608,000, industrial buildings at $2,348,000, earthwork, irrigation and drainage at $2,078,000, sewers at $1,396,000 and federal government at $3,054,000, all as compared with last weeks figures.

The larger contracts include a generating plant for the Rochester Gas & Electric Co., Rochester, N. Y., $750,000; sewage disposal plant, sewage pumping station and grit chambers for District Commissioners, Washington, D. C., $650,000 and $459,000, respectively; four turbines for Bonneville Dam, Oregon, $1,135,000; highway awards by Texas, $1,254,000.

State and municipal bond sales totaled $6,667,000 for the week. There were no PWA allotments for either federal or non-federal work.

CONTRACTS
(Thousands of Dollars)

	Weekly Average May 1934	Prev. 4 Weeks	Week May 9 1935
Federal Government	$3,144	$4,037	$3,054
State and municipal	14,597	12,864	9,939
Total public	$17,741	$16,901	$12,993
Total private	5,607	10,639	4,467
Week's total	$23,348	$27,540	$17,460

Cumulative to date:
1934...$531,050,000 1935...$460,084,000

NEW PRODUCTIVE CAPITAL
(Thousands of Dollars)

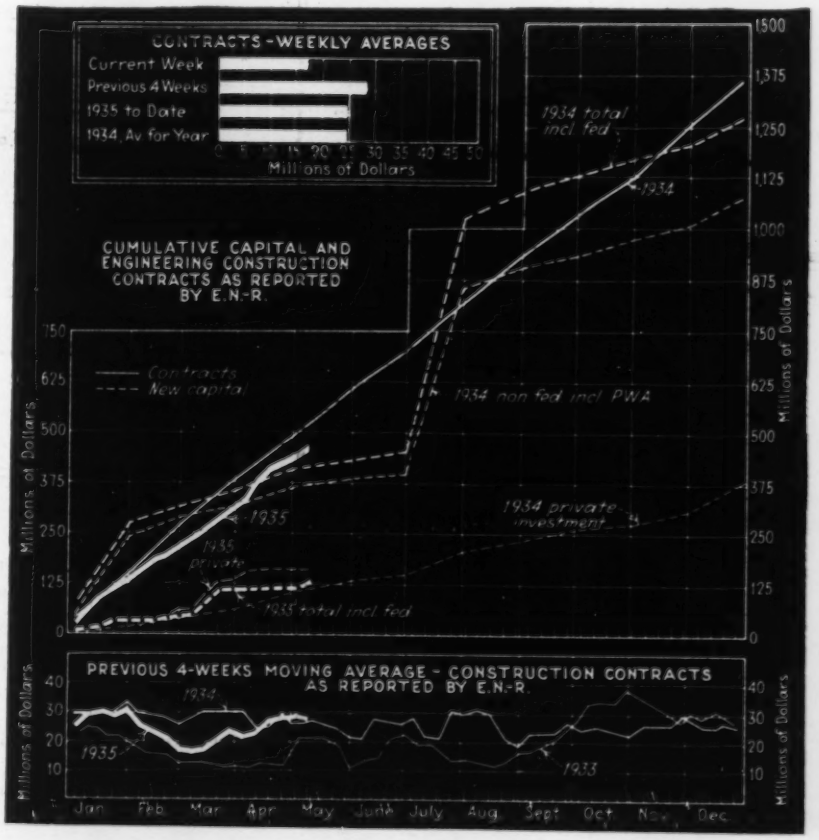
1935	Week May 9	Cumulative
State and municipal	$6,667	$152,749
PWA allotments, S&M.	.....	—42,541
RFC loans, S&M	.....	84
Corporate issues	.....	.....
PWA allotments, private	.....	8,509
Total, Non-Federal	$6,667	$118,801
PWA allotments, Federal Constr.	.....	8,589
Total new capital	$6,667	$127,390

Cumulative to date:
1934...$413,565,000 1935...$127,390,000

Note: These figures include private bonds, and stocks sold for productive purposes; state and municipal bonds for construction; PWA loans and grants to states and municipalities, including the special highway funds; PWA private loans, and allotments for Federal construction. Negative amounts in PWA totals indicate excess of rescissions and reductions over reallotments and increases in outstanding allotments.

INDEX NUMBER

E.N.R.-Cost	1913 = 100	1926 = 100	E.N.R.-Volume	1913 = 100	1926 = 100
May, 1935	**194.06**	**93.28**	**Apr., 1935**	**130**	**57**
Apr., 1935	194.50	93.49	Mar., 1935	106	44
May, 1934	199.61	95.95	Apr., 1934	109	48
1934 (Av.)	198.10	95.23	1934 (Av.)	114	50
1933 (Av.)	170.18	81.80	1933 (Av.)	102	47
1932 (Av.)	156.97	75.45	1932 (Av.)	127	56



Current Construction Unit Prices

Comparison of Steel and Concrete Pipelines

TACOMA, Wash., let a contract on Jan. 31, 1935, for the 44,846-ft. Green River gravity water pipeline based on lowest annual cost of various combinations of steel and concrete pipe as revealed by alternate bids. Bids were called for on seven propositions; Prop. 1 was for 10,755 ft. of 42-in. steel pipe, required regardless of the type of pipe selected for the remainder of the line. Prop. 2, 3 and 4 included the 42-in. line and in addition were for 54-in. steel pipelines of various lengths; Prop. 5, 6 and 7 were 54-in. Lock Joint concrete lines. The bids for steel pipe were further broken down into additional alternates for types of protection. Three types were considered: Type A, spun coal tar lining with double coal tar and asbestos wrap outside; Type B, spun coal tar lining with coal tar and cement wrap exterior; three coats of paint inside and outside. No bids were received for Type B protection. Although all bids showed a greater first cost of the Type A over paint coating, the former showed up best in annual costs, because the Type A was given an assigned life of 52 years, as compared with a life of 45 years granted to paint coating. Concrete pipe was given an assigned life of 60 years in the annual cost comparisons. The lowest annual cost was secured by combining Prop. 1 and 7, the 42-in. section of steel, Type A coating, and the remainder of 54-in. concrete pipe. Contract was awarded on this basis. Following are four tables showing the total of low bids, combinations of alternates with annual cost of each, details of annual cost comparisons and unit prices of principal items of the low bidders. The work is under the direction of the Department of Public Utilities, W. A. Kunigk, Supt. of Water Division. PWA wage rates and regulations apply.

TABLE I—COMBINATIONS OF PROPOSITIONS AND LOW BIDS

Prop. 1 and 7:	Prop. 1—10,755 ft. of 42-in. steel pipe	
	Prop. 7—34,091 ft. of 54-in. concrete pipe	
	Total length	44,846
Prop. 2 and 6:	Prop. 2—10,755 ft. of 42-in. steel pipe	
	12,022 ft. of 54-in. steel pipe	
	Prop. 6—22,069 ft. of 54-in. concrete pipe	
	Total length	44,846
Prop. 3 and 5:	Prop. 3—10,755 ft. of 42-in. steel pipe	
	22,069 ft. of 54-in. steel pipe	
	Prop. 5—12,012 ft. of 54-in. concrete pipe	
	Total length	44,846
Prop. 4:	10,755 ft. of 42-in. steel pipe	
	34,091 ft. of 54-in. steel pipe	
	Total length	44,846

Low Bidders:

A—Puget Sound Machinery Depot, Seattle:		
Prop. 1	Type A pipe coating	$124,598*
	Cold paint pipe coating	108,012
Prop. 2	Type A pipe coating	305,439
	Cold paint pipe coating	262,570
Prop. 3	Type A pipe coating	450,116
	Cold paint pipe coating	385,948
Prop. 4	Type A pipe coating	628,708
	Cold paint pipe coating	538,092
B—American Concrete Pipe Co. of Washington, Tacoma:		
Prop. 5	Concrete pipe	215,064
Prop. 6	Concrete pipe	360,292
Prop. 7	Concrete pipe	526,225*

*Contract

TABLE II—TOTAL ANNUAL COST OF VARIOUS COMBINATIONS
Based on Type A Coating of Steel Pipe

Combination	Total Length	Total Annual Cost
Prop. 1 and 7	44,846 ft.	$12,240.08
Prop. 2 and 6	44,846 ft.	12,996.15
Prop. 3 and 5	44,846 ft.	13,397.14
Prop. 4	44,846 ft.	13,277.89

TABLE III—DETAILS OF ANNUAL COST COMPARISONS—STEEL AND CONCRETE PIPE

Prop	Length, Ft.	Low Bidder	Total of Bid	Mill Inspection	Eng. Superv., Carrying Chgs., Misc. Exp.	Total Cost	Assigned Life, Yrs.	Annual Cost
Steel Pipe								
1*	10,755	A	Type A coating—$124,597.75	$ 640.84	$23,233.21	$148,471.80	52	$2,855.23
		A	Paint coating — 108,011.95	640.84	22,901.50	131,554.29	45	2,923.43
2	22,777	A	Type A coating— 305,438.91	921.32	36,280.44	342,640.67	52	6,589.29
		A	Paint coating — 262,570.03	921.32	35,423.07	298,914.42	45	6,642.54
3	32,824	A	Type A coating— 450,116.03	1,571.44	46,678.89	498,366.36	52	9,583.97
		A	Paint coating — 385,947.73	1,571.44	45,395.52	432,914.69	45	9,620.33
4	44,846	A	Type A coating— 628,708.42	2,056.56	59,685.24	690,450.22	52	13,277.89
		A	Paint coating — 538,091.72	2,056.56	57,872.91	598,021.19	45	13,289.36
Concrete Pipe								
5	12,012	B	$215,064.33	.....	$13,726.09	$228,790.42	60	$3,813.17
6	22,069	B	360,292.18	.....	24,122.54	384,414.72	60	6,406.91
7	34,091	B	526,224.99	.....	36,866.00	563,090.99	60	9,384.85

*Note—Prop. 1 is 42-in. dia., all other propositions are 54-in. pipe, with the 42-in. steel section included in Prop. 2, 3 and 4.

TABLE IV—LOW UNIT BIDS ON PRINCIPAL ITEMS, SEVEN PROPOSITIONS—TACOMA PIPELINE

Item (Principal Items Only)	Prop. No. 1		Prop. No. 2		Prop. No. 3		Prop No. 4		Prop. No. 5		Prop. No. 6		Prop. No. 7	
	Quan.	Bidder A	Quan.	Bidder A	Quan.	Bidder A	Quan.	Bidder A	Quan.	Bidder B	Quan.	Bidder B	Quan.	Bidder B
1. Clearing, grubbing, road—lump sum	.....	$200.00	.....	$8,100	.....	$14,900	.....	$23,000	.....	$5,775	.....	$11,025	.....	$21,525
2. Fencing—lin.ft.	.....	.....	10,000	.10	30,000	.10	40,000	.10	10,000	.05	30,000	.05	40,000	.05
3. Excav. and backfill, 42-in. line—lin.ft.	10,770	.95	10,770	.95	10,770	.95	10,770	.95	.....	.....	.....	.....	.....	.....
4. Excav. and backfill, 54-in. line—lin.ft.	.....	.....	12,022	1.30	21,909	1.25	33,931	1.20	12,030	1.16	22,000	1.26	33,950	1.16
5. Bank run sand and gravel—cu.yd.	1,800	1.00	2,200	1.10	2,000	1.00	2,400	1.00	400	1.25	200	1.25	600	1.25
6. Steel pipe, 42x $\frac{7}{16}$ in.—lin.ft.	10,775	7.35	10,755	7.15	10,755	7.00	10,755	7.00	.....	.....	.....	.....	.....	.....
7. Steel pipe specials, 42x $\frac{7}{16}$ in.—lump sum	.....	1,550	.....	1,550	.....	1,550	.....	1,550	.....	.....	.....	.....	.....	.....
8. Steel pipe, 54x $\frac{7}{16}$ in.—lin.ft.	.....	.....	5,622	9.20	11,700	9.00	17,322	9.00	.....	.....	.....	.....	.....	.....
9. Steep pipe, 54x $\frac{1}{2}$ in.—lin.ft.	.....	.....	6,400	10.20	10,369	10.00	16,769	10.00	.....	.....	180	12.80	180	12.80
10. Lock joint concrete pipe, 54 in.—lin.ft.	.....	.....	.....	.....	.....	.....	.....	.....	12,012	15.80	21,889	13.98	33,911	13.10
11. Std. air value chambers—each	3	110.00	4	110.00	5	100.00	6	100.00	1	152.40	2	152.40	3	152.40
12. Std. blowoff chambers—each	1	150.00	4	150.00	6	140.00	9	140.00	3	117.70	5	117.70	8	117.70
13. Comb. A. V. and M. H. chambers—each	2	200.00	7	200.00	9	190.00	14	190.00	5	164.80	7	164.80	12	164.80
14. Comb. B. O. and M. H. chambers—each	5	160.00	8	160.00	8	150.00	11	150.00	3	126.95	3	126.95	6	126.95
15. Std. manhole chambers—each	2	150.00	2	150.00	2	140.00	2	140.00	.....	.....	.....	.....	.....	.....
16. Encasement, railroad crossings—each	3	375.00	3	375.00	3	350.00	3	350.00	.....	.....	.....	.....	.....	.....
17. Wooden gutters—lin.ft.	.....	.....	950	.40	950	.40	1,900	.40	950	.22	950	.22	1,900	.22
18. Wooden flumes—lin.ft.	.....	.....	200	.40	470	.40	670	.40	200	.36	470	.36	670	.36
19. Service connections, 2 in.—each	12	11.00	31	10.00	60	10.00	79	10.00	19	14.42	48	14.42	67	14.42
20. Service connections, 4 in.—each	.....	.....	2	8.00	4	8.00	6	8.00	2	13.60	4	13.60	6	13.60
21. Type A coating, 42-in. steel pipe—lin.ft.	10,770	2.40	10,770	2.32	10,770	2.27	10,770	2.27	.....	.....	.....	.....	.....	.....
22. Type A coating, 54-in. steel pipe—lin.ft.	.....	.....	12,022	3.08	22,069	3.02	34,091	3.02	.....	.....	.....	.....	.....	.....
23. Paint coating, 42-in. steel pipe—lin.ft.	10,770	.86	10,770	.84	10,770	.82	10,770	.82	.....	.....	.....	.....	.....	.....
24. Paint coating, 54-in. steel pipe—lin.ft.	.....	.....	12,022	.84	22,069	.82	34,091	.82	.....	.....	.....	.....	.....	.....